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CURRENT OBSERVATIONS IN THE CHANNELS OF THE CANADIAN ARCTIC ARCHIPELAGO ADJACENT TO BATHURST ISLAND

by

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ABSTRACT

The results of current meter measurements in Byam and Austin Channels and Crozier and Pullen Straits, all in the vicinity of Bathurst Island, N.W.T. are presented. The mean flow, long period oscillations and tidal oscillations are discussed. The records are dominated by tidal oscillations. It was found that mean flows averaged less than 5 cm s^{-1} while tidal oscillations could be as high as 30 cm s^{-1}.

The total transport in the channels is 0.2 x 10^6 m^3 s^{-1} which is less than 5% of the total exchange between the Arctic Ocean and the rest of the world ocean.

Year-long current records at two sites show augmented currents in late October and late December. Although these larger currents are probably associated with the atmospheric pressure difference between the Arctic Ocean and Lancaster Sound, no significant correlation was found.

The measured density stratification in Crozier Strait was used to compute internal wave modes and the current observations were fitted to these modes to determine the amplitudes of the lowest mode internal waves. Due to the very weak stratification, the internal tidal streams appear to be about 1/10 the amplitude of the barotropic tidal streams.

The rotation of the major axes of the tidal ellipses in close proximity to the bottom and the under-side of the ice were found to agree with theory which predicts the rotation to be determined by the sense of polarization of the rotating current vectors.

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1. INTRODUCTION

An interest in the currents of Byam and Austin Channels together with Crozier and Pullen Straits is a direct result of the Polar Gas proposal to transport natural gas by pipeline from the fields on Melville Island in the Northwest Territories to markets in southern Canada. The proposal included necessary crossings of a number of marine channels few of which had ever been studied from an oceanographic viewpoint. A detailed knowledge of currents was of particular importance to provide the knowledge for an adequate design of the pipeline and for suitable installation techniques at marine crossings.

The principals of the Polar Gas Project, through their consultants, Montreal Engineering Company Limited, entered into an agreement with the Frozen Sea Research Group (F.S.R.G.) of the Institute of Ocean Sciences, Patricia Bay, at Sidney, B.C. to conduct an oceanographic program in those channels where F.S.R.G. was equipped to operate. The principal goal was to obtain current measurements adjacent to the sea floor, as these were clearly needed to insure the integrity of the pipeline after installation, including consideration of movement of bottom sediments. It was also decided to measure currents adjacent to the sea ice in order to obtain information on the local movement of oil under ice as might occur in the event of an offshore oil well blowout in the Sverdrup Basin. Current measurements in Byam and Austin Channels in 1976 were limited to these two boundary regions by the need to fix the recording current meters to a rigid surface in order to obtain information on current direction. The close proximity of the north magnetic pole precluded the use of magnetic compasses, the normal direction reference built into current meters designed for use at more southern latitudes. In 1977 current measurements were taken in Crozier and Pullen Straits by which time a method of measuring currents at mid-depths as well as in the boundaries was available. Compared to Byam and Austin Channels a significantly greater proportion of the data obtained in Crozier and Pullen Straits was of oceanographic interest. This fact is reflected in the emphasis given in discussion of data which follows in this report.

In addition to current measurements data on tides and water structure (temperature and salinity profiles) were obtained.

a) Bathymetry

The waters of the Canadian Archipelago everywhere overly the continental shelf and separate the islands with numerous shallow channels. Depths are generally less than 600 metres although a few deeper basins exist as a result of glacial overdeepening. Flow through the Archipelago is limited by one or more sills. The geographical location of Byam and Austin Channels and Crozier and Pullen Straits is shown in Figure 1.

Byam and Austin Channels

The bathymetry of Byam and Austin Channels is illustrated in Figure 2. Austin Channel is the deeper of the two channels with a few locations reaching 250 metres. The limiting sill depth just to the north is about 200 metres. Connection to the Arctic Ocean from the north is restricted by a 400

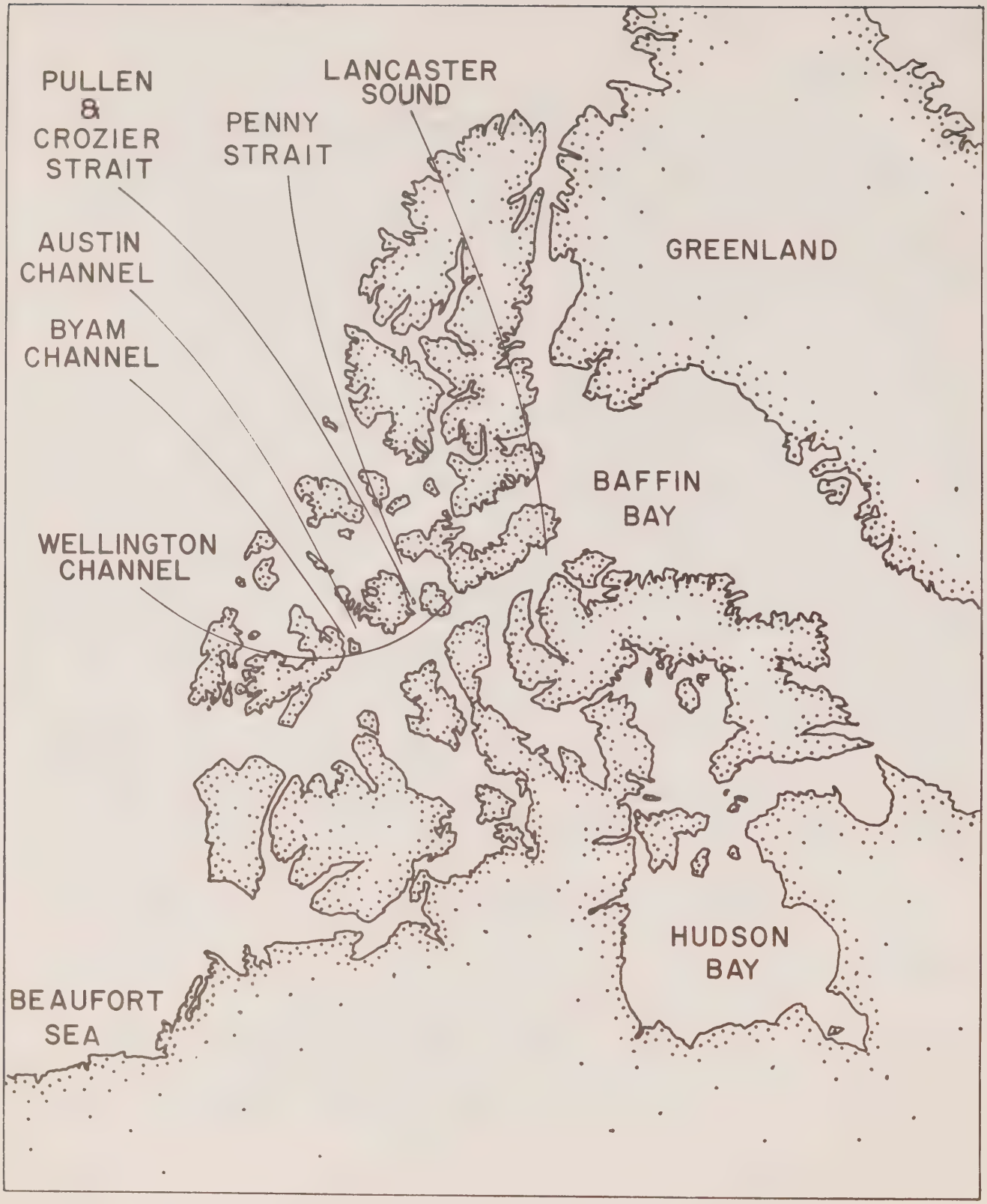


FIGURE 1. Geographical location of Channels.

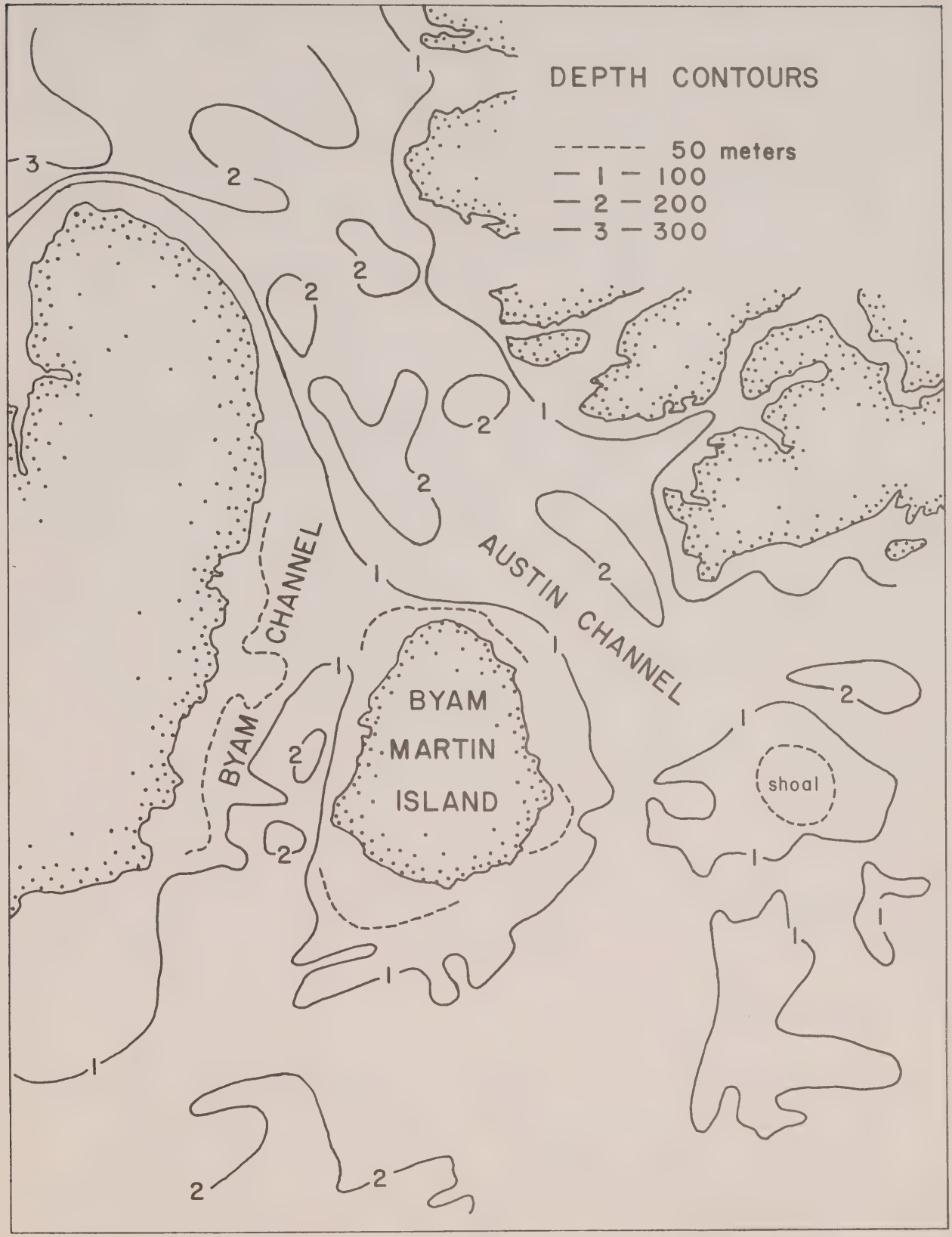


FIGURE 2. Bathymetry of Byam and Austin Channels

metre sill at the entrance to Prince Gustaf Adolf Sea. A shoal is centered at the south end of Austin Channel from which point depths west to Byam Martin Island barely exceed 100 metres. East of the shoal, depths are generally less than 150 metres. In Byam Channel a sill is located between the north end of Byam Martin Island and Melville Island to the west. Flow over this sill is restricted to depths slightly less than 100 metres. South of the Byam sill water depths increase to form a channel nearly 200 metres deep extending south to the deeper waters of Viscount Melville Sound. To the west Viscount Melville Sound communicates with the Arctic Ocean via M'Clure Strait to depths approaching 480 metres. The eastern end of Viscount Melville Sound becomes progressively shallower south of Austin Channel. To the east the Sound is connected to Baffin Bay via Barrow Strait and Lancaster Sound. Here water depths reach their minimum in Barrow Strait, whose estimated sill depth is 140 metres.

Crozier and Pullen Straits

The bathymetry of Crozier and Pullen Straits is illustrated in Figure 3. Crozier Strait is remarkably deep for its width, a feature which can probably be attributed to a geological fault extending along the axis of the strait. A sill whose depth probably does not reach 100 metres extends across Crozier Strait near Milne Island. Soundings in this area are limited to a single ship's track so that this depth is at best an educated guess although the existance of the sill is almost certain. Water depths to the east and north of Milne Island are unknown, but based on soundings farther north and east are probably not more than 50 metres. The trench comprising the major portion of Crozier Strait extends southward from the sill where it reaches a depth of 400 metres before it shoals again in McDougal Sound. The water continues to shoal into Barrow Strait where depths are generally between 100 and 200 metres. A cross-section from Milne Island to Barrow Strait is shown in Figure 4. In contrast to Crozier, Pullen Strait is shallow with maximum recorded depths near 75 metres. North of Pullen a limited number of soundings suggest water depth of less than 30 metres. Between Pullen Strait and McDougall Sound to the south water depths seldom exceed 100 metres until the trench associated with Crozier Strait is approached. To the south and east Crozier and Pullen Straits are separated from Baffin Bay to Barrow Strait with its sill depth near 140 metres. To the north Penny Strait, with its sill depth near 100 metres, separates Crozier and Pullen Straits from the various channels leading to the Arctic Ocean. Wellington Channel to the north and east provides a connection to the east end of Barrow Strait. This route contains a chain of islands and sills where water depths appear not to exceed 75 metres.

b) Current Meter Locations

A detailed chart of Byam and Austin Channels is given in Figure 5. The five current meter sites in each channel are labelled B1, A1 etc. A cross section of the two channels, given in Figure 6 shows the location of meters on the surface and sea floor at each site. Useful data were not recovered from all meters for a variety of reasons, thus the meters at B1 and B4 bottom and B3 top have been omitted from this figure. Similarly, a detailed chart and cross section of Crozier and Pullen Straits are presented in Figures 7 and 8 respectively. The cross section shows the position of the mid-depth current meters added for this study.

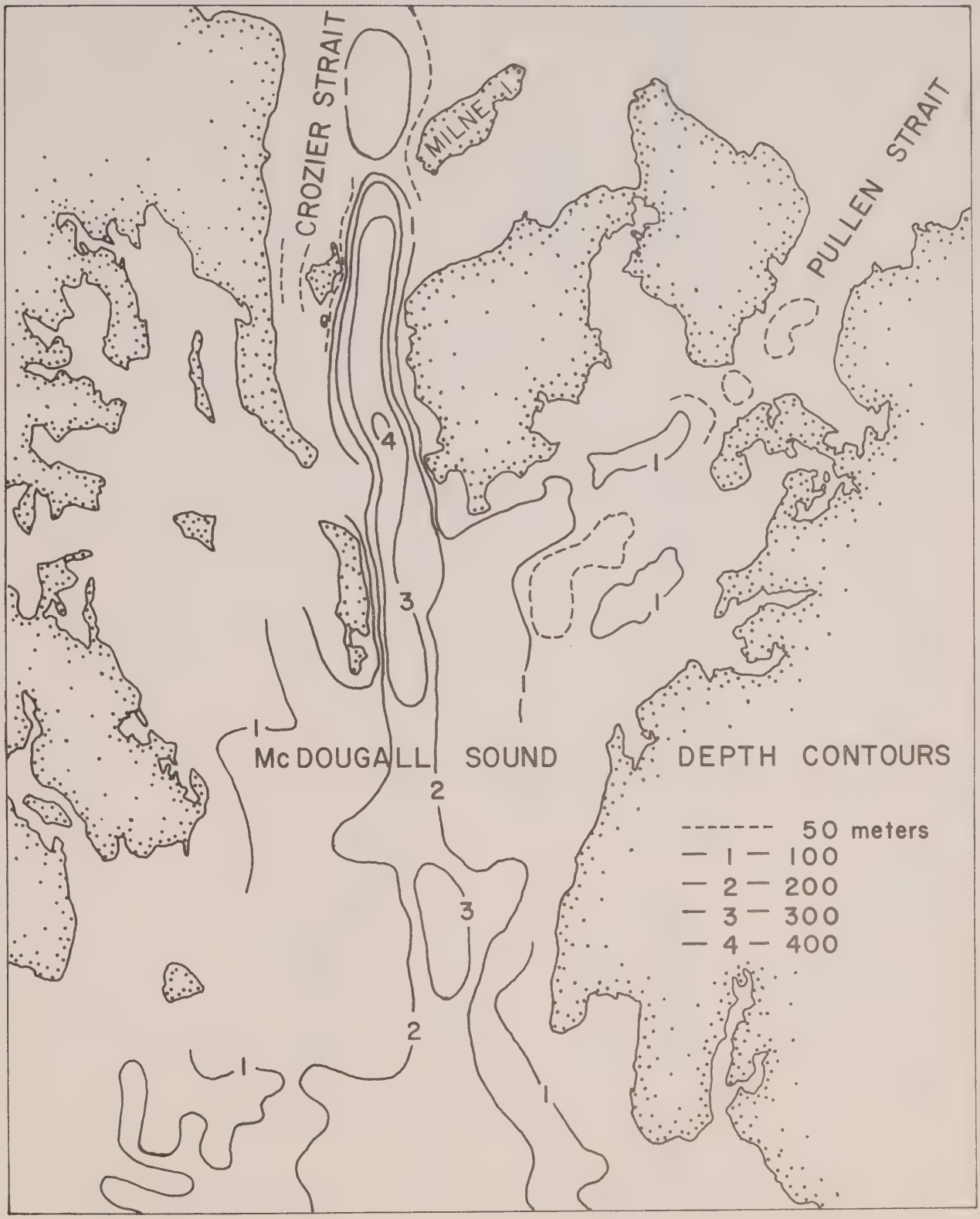


FIGURE 3. Bathymetry of Crozier and Pullen Straits.

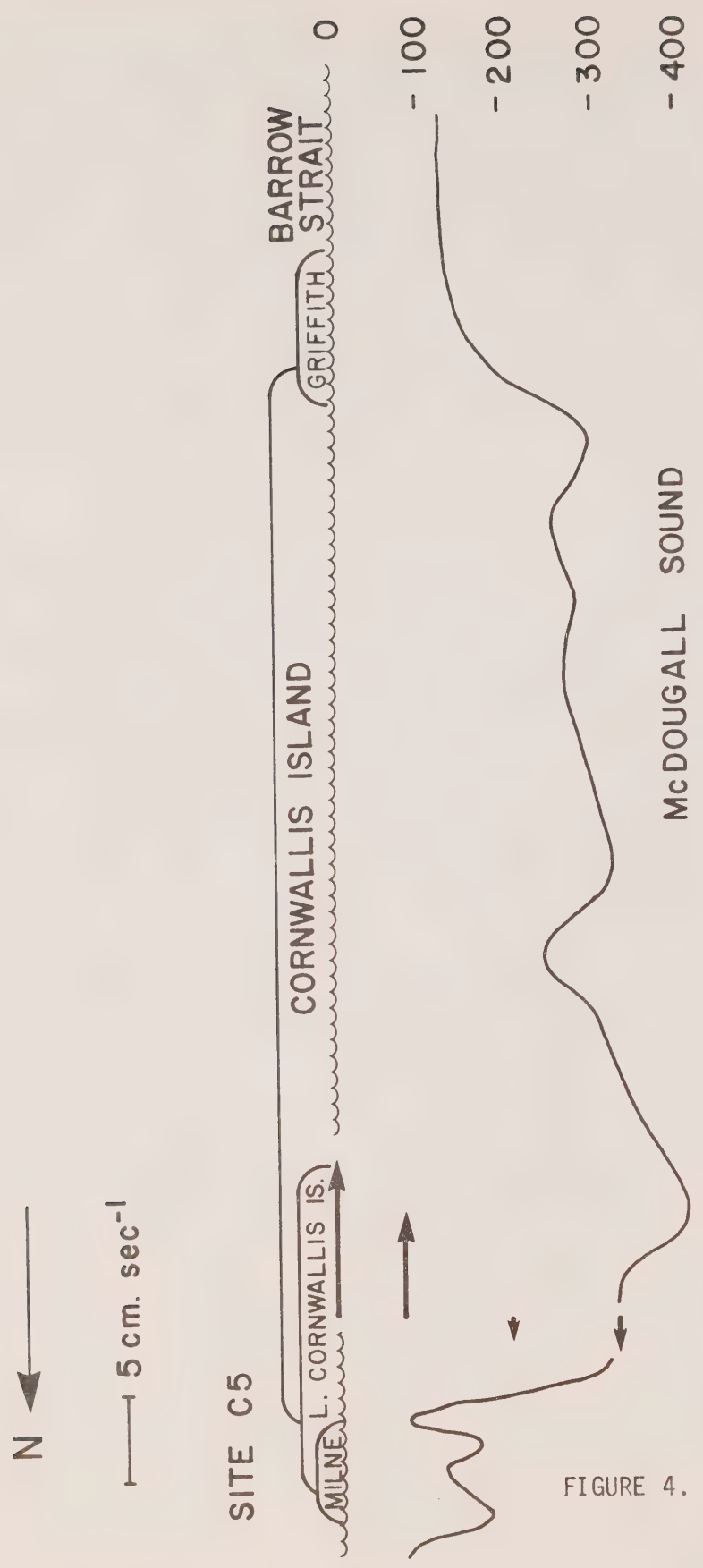


FIGURE 4. Cross-section, Milne Island to Barrow Strait.

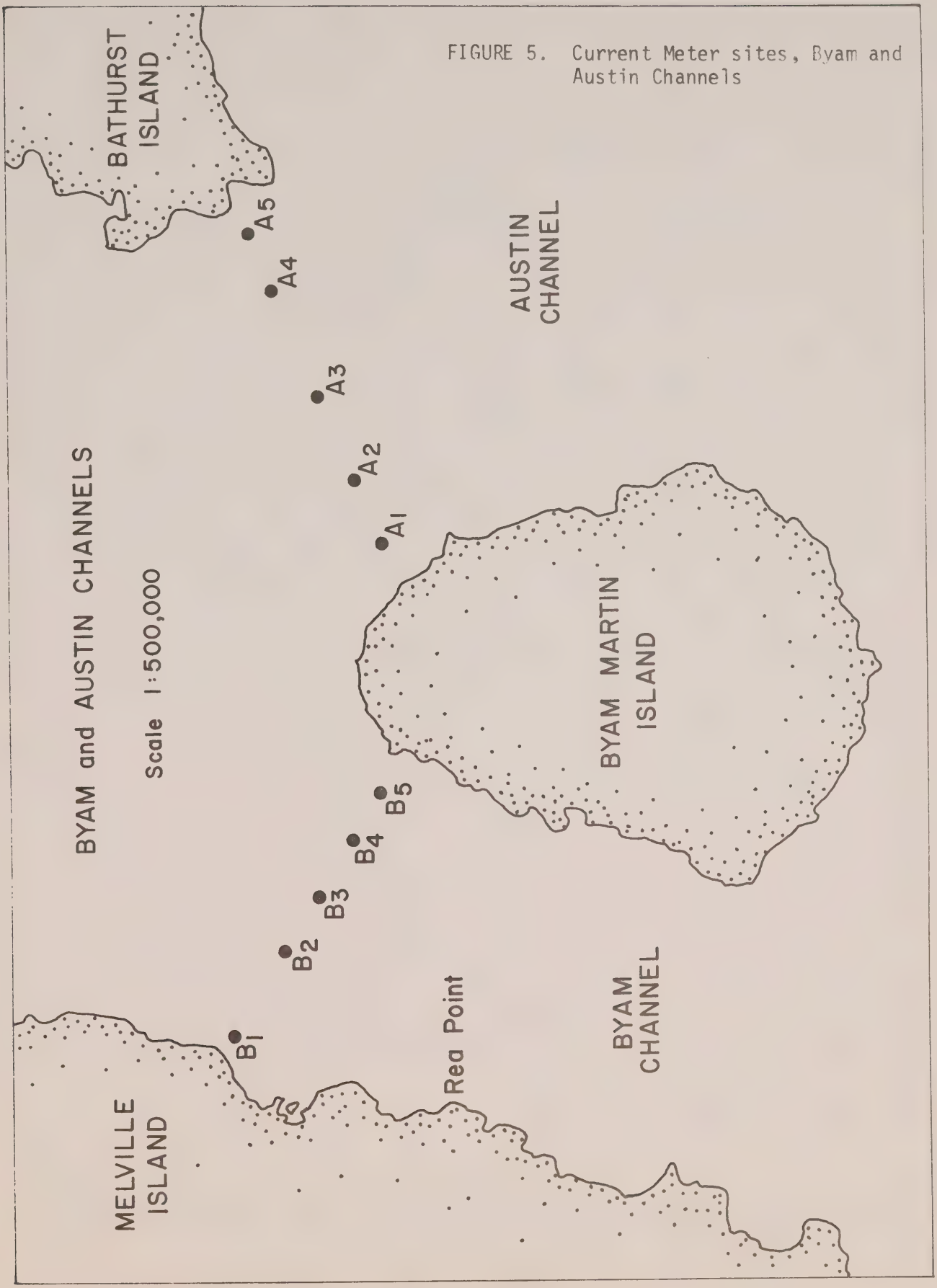


FIGURE 5. Current Meter sites, Byam and Austin Channels

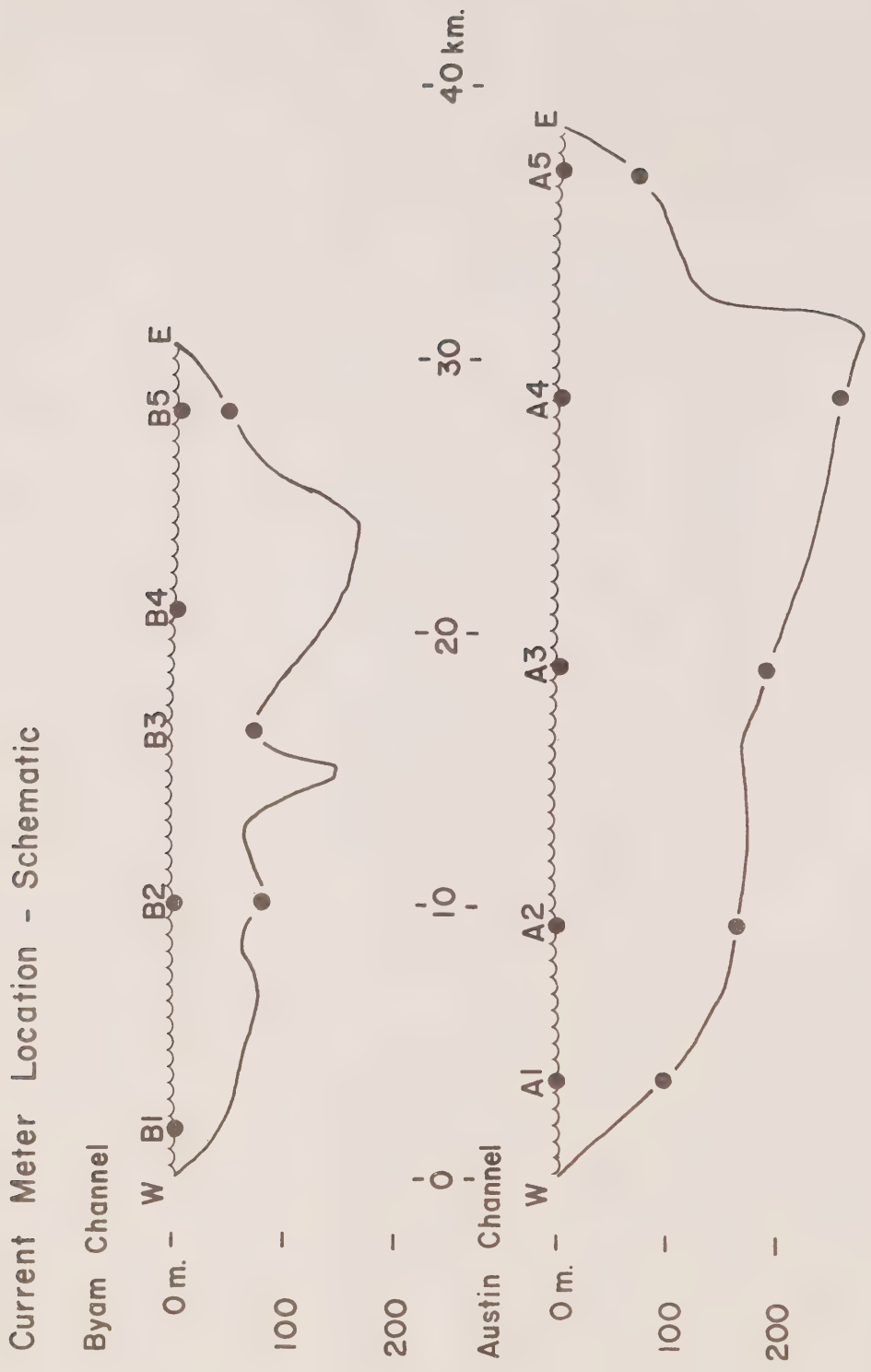


FIGURE 6. Current Meter distribution in Byam and Austin Channels.

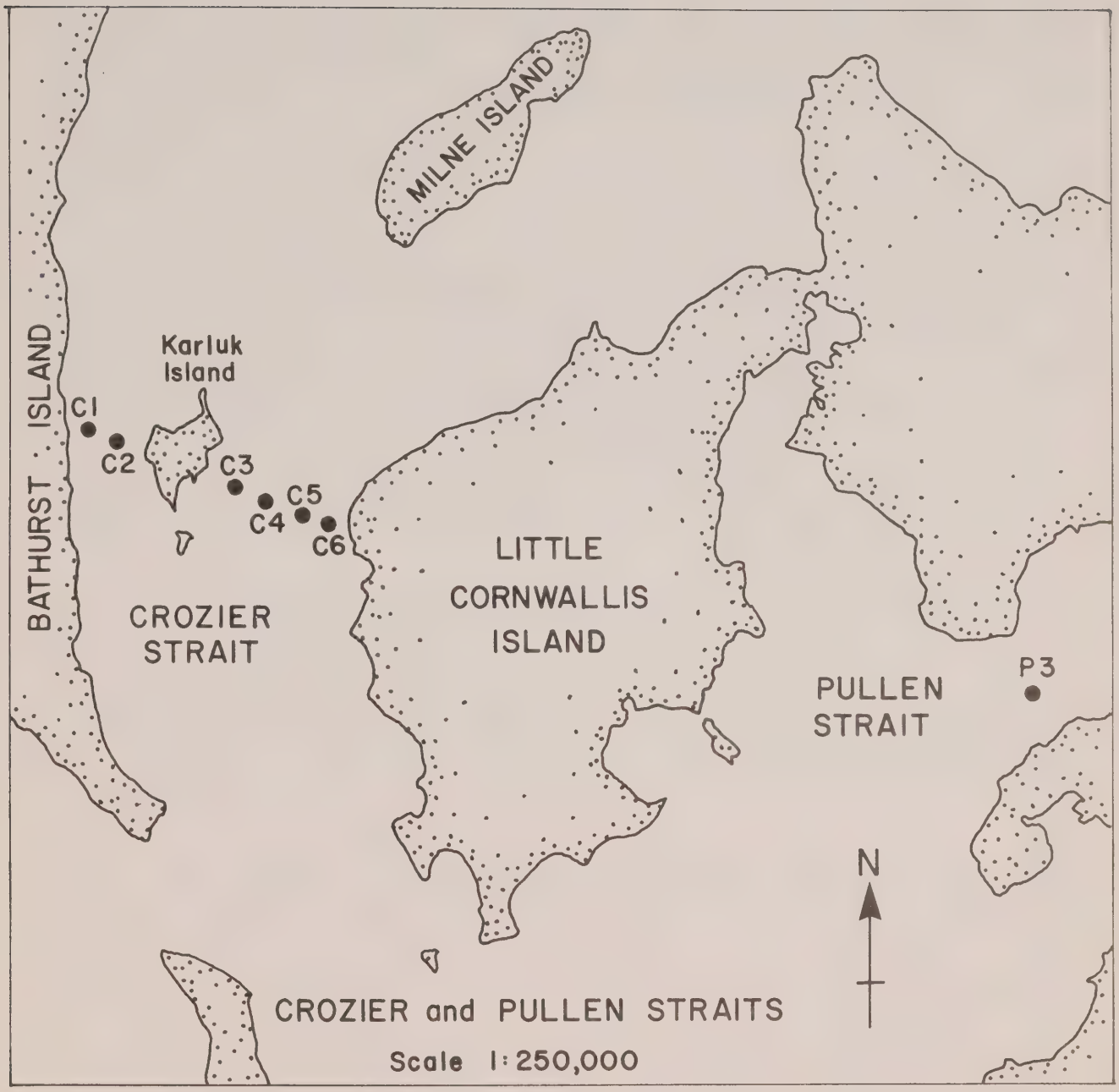


FIGURE 7. Current Meter sites, Crozier and Pullen Straits.

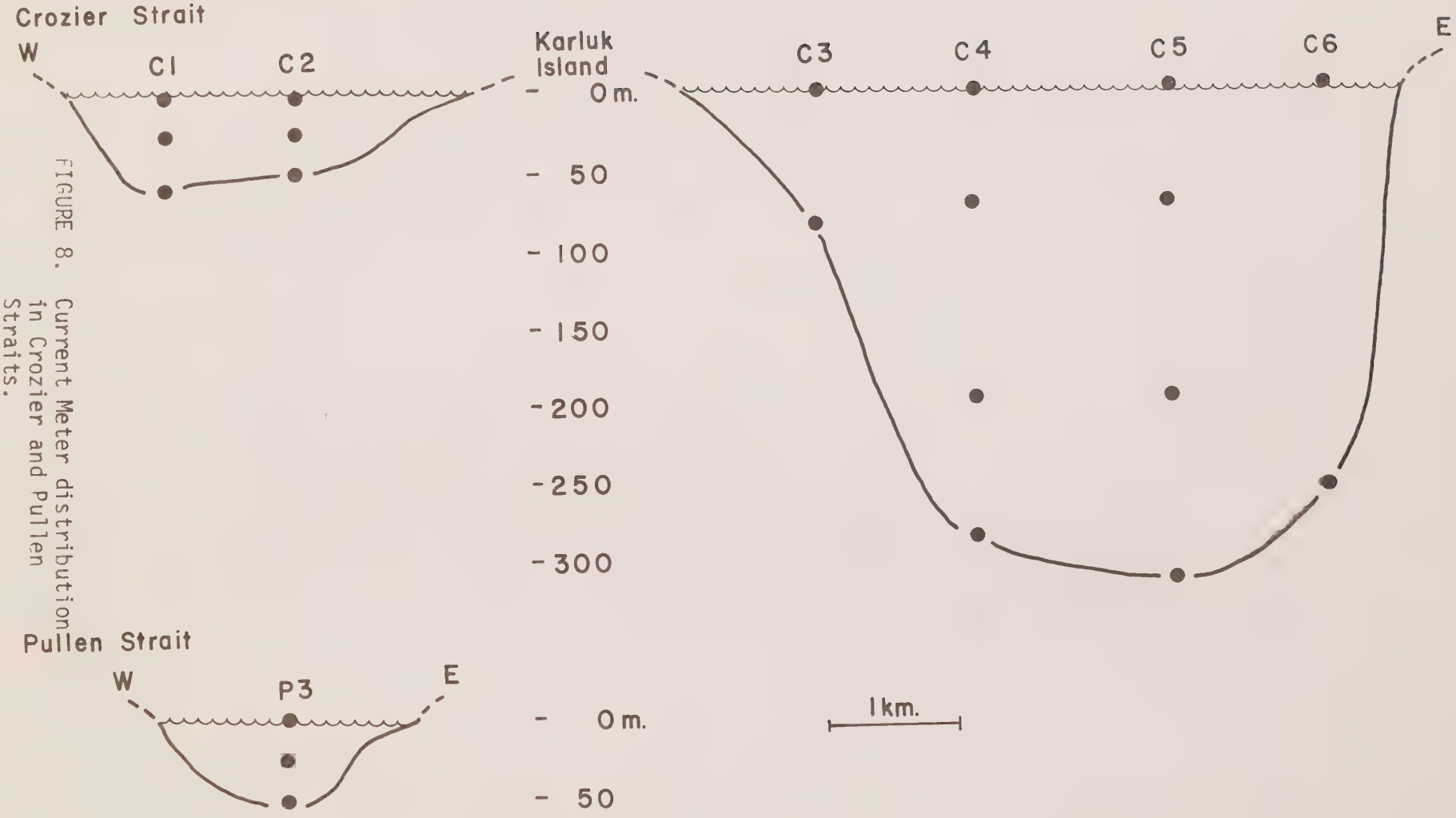


FIGURE 8. Current Meter distribution in Crozier and Pullen Straits.

The geographic location of each site was determined prior to installation of the current meters. The positions were later fixed with a Del Norte Range/Range system with slaves at two known geodetic survey markers. For each channel a different pair of geodetic markers was used. The master readout unit was carried in the tracked vehicles so that the distance to each slave could be determined while moving. The system was accurate to 5 metres and had a resolution of 1 metre. The current meters were deployed as close to the preselected position as ice conditions permitted and in each case the final location was noted.

c) Instrumentation

Current Meters

All recording current meters used were the same make and model: Aanderaa RC-4. Meters were modified in-house by replacing the large conventional 1 metre long vane by a smaller 10 cm long vane which, for mid-depth and bottom meters, was mounted below the pressure case with its axis of rotation coinciding with the axis of the pressure case. This modification permitted deployment of the meter through a 23 cm diameter hole drilled through the sea ice. For the sub-ice current meters the vane and rotor were separated from the pressure case containing the control and recording electronics. As an option, the meters could be equipped with sensors to measure temperature, conductivity and pressure in addition to current speed and direction. The performance specification for the meter is given in Table 1.

Three different systems were used to mount the meters just below the sea ice, at mid-depths and on the sea floor respectively. These are shown diagramatically in Figure 9. For the sub-ice meters the rotor and vane were suspended from the sea ice with sufficient clearance between the bottom of the ice and the top of the rotor to allow for ice growth. This system measured current speed 15 to 20 cm below the ice bottom with current direction measured 15 cm deeper. The sensors were hard-wired to the Aanderaa data logger located below the ice a few metres away. This configuration is depicted in Figure 9 (a).

Mid-depth current meters were located in Crozier and Pullen Straits at 25, 75 and 200 metres depths depending on location with some sites lacking meters at mid-depth. Two lines of 3 mm diameter space lay were suspended from the land-fast sea ice from points 30 metres apart. These lines were brought together at the prescribed depth with the current meter at the point of the "V". The meter itself was hung from the centre of a 3.7 metre long boom with 11.4 kg weights at each end. The suspension lines were attached to the ends of the boom. This configuration (see Figure 9 (b)) provided excellent resistance to rotation. The current drag on the meter and suspension lines caused the meter to swing and rise to some small degree during the periods of stronger current flow. This motion was sensed by the pressure transducer included in the two 200 metre mid-depth meters. Any swinging motion appears to have a period of a few hours so that the resulting error in current speed is considered negligible. A test was conducted to determine if the suspension system would undergo high frequency modes of oscillation which would be recorded as erroneous (higher) current speeds. For this test a recording current meter was temporarily left suspended at a 200 metre depth for 72 hours with a scan rate of once every 30 seconds. No high frequency oscillations were detected.

TABLE 1.

Performance of Aanderaa RC-4 Current Meter

	Accuracy	Resolution (least count)		
Current speed	± 0.8	0.2/0.5	cm sec^{-1}	note 1,2
Current Direction (top)	± 5	0.5	degrees	note 3
Current Direction (mid)	± 5	0.5	degrees	note 3
Current Direction (bottom)	± 7	0.5	degrees	note 3
Temperature	± 0.1	0.03	°C.	
Conductivity	± 0.1	0.07	mmho cm^{-1}	
Pressure	± 7.0	0.7	decibars	
Salinity	± 0.15		°/oo	
Time Drift (Aanderaa)	± 2		sec day^{-1}	
(Sea Data)	± 2		sec day^{-1}	

Note 1. Accuracy as quoted in Models RC, -4 and RC, -5 Aanderaa Recording Current Meters. National Oceanographic Instrumentation Center Instrument Fact Sheet IRS-75002. U.S.A. Dept. of Commerce, Washington D.C., July 1974.

2. The value of resolution depends on the particular meter used.

3. Estimates of accuracy are subjective. The larger value for the bottom current meter reflects the use of the gyro.

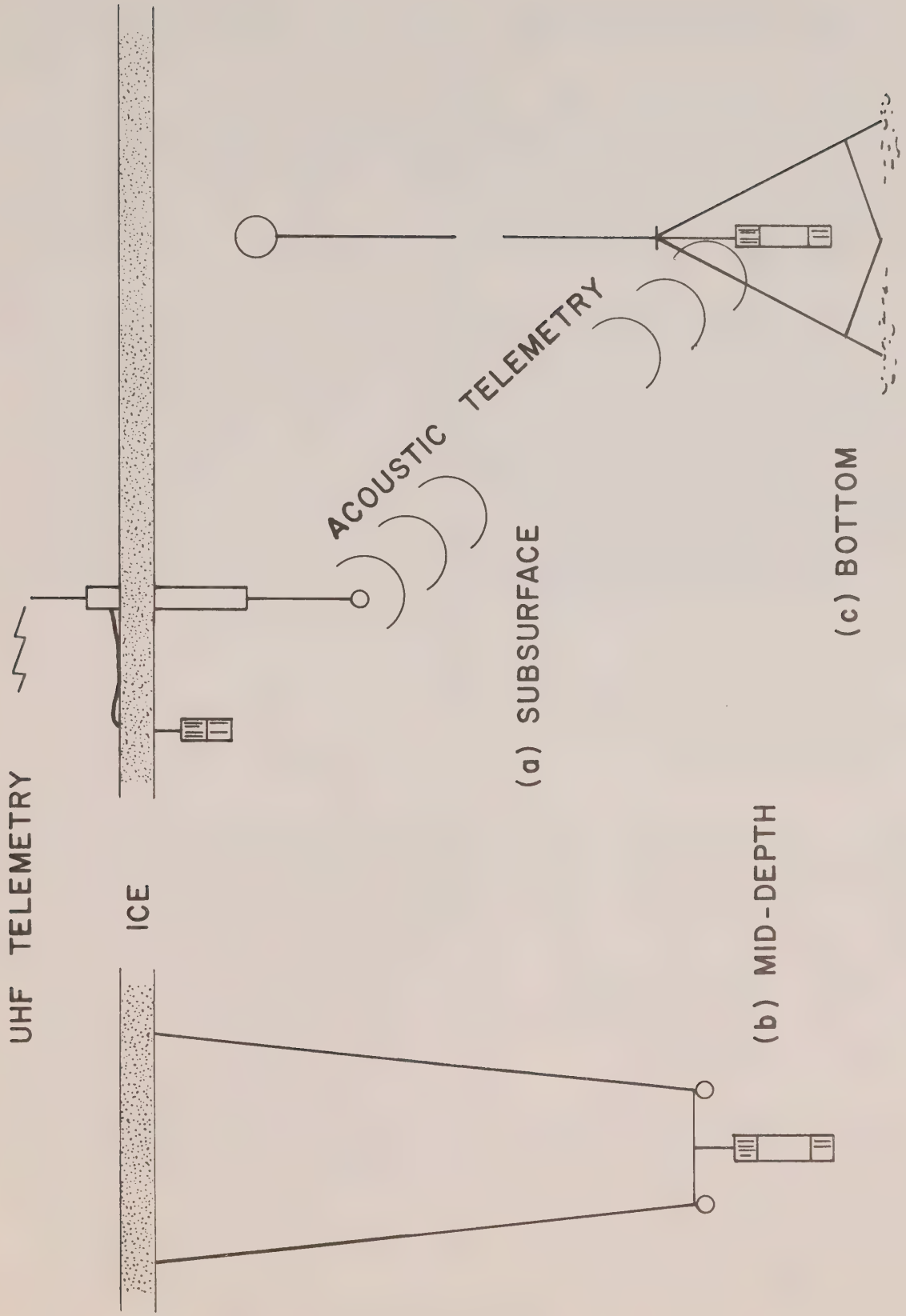


FIGURE 9. Mounting configurations.

As both the sub-ice and mid-depth meters were attached to land fast sea ice their azimuth was constant throughout the period of data recording.

Bottom current meters were suspended from the apex of a pyramid-shaped frame formed by four aluminum poles as depicted in Figure 9 (c). The azimuth of bottom meters was determined by measuring the fixed current meter orientation immediately after installation by releasing a gyro which was returned to the surface. A rotor measured the current speed 2 metres above the sea floor. The current direction was measured by a vane located 60 cm below the rotor.

The data sensed at the bottom current meters were transmitted hourly as a train of acoustic pulses which was received by a hydrophone installed with the subsurface current meter equipment package. These data, as well as hourly information collected by the sub-ice meter were relayed by an UHF radio transmitter to a receiver located on shore where data were recorded on a cassette magnetic tape, a part of a Sea Data model 610 system. The current meters simultaneously recorded data internally on magnetic tape. This redundancy in data recording provided an insurance against the high probability of losing a meter along with its internally recorded data. The internally recorded data however, were of higher quality than the telemetered data and so were used for analysis whenever possible. The mid-depth meters in Crozier and Pullen Straits used no data telemetry.

Tide Gauge

An 84 day tide record was obtained in Crozier Channel using an Aanderaa model WLR-4 water level recorder.

d) Data Record

The recording current meter mountings were designed to deploy the current meters through the sea ice using specially designed tracked vehicles. In general the meters were installed in early spring when ice thickness and visibility were adequate for operations. The sub-ice and mid-depth meters which were suspended from the sea ice were recovered before ice breakup in late June or early July. The bottom meters were designed to operate in place for one year although 5 of the 7 bottom meters in Crozier and Pullen Straits were recovered during the open water period of the same year in which they were installed. A bar graph showing duration of installation for each meter is shown in Figure 10.

The current data are best sumarized by histograms of current speed, current direction and number of occurences. Histograms were constructed for each of the current records and are reproduced in Appendix A. In these histograms the third dimension (number of occurences) is shown by a number occupying the appropriate position in the speed and direction grid. The speed columns span 3 cm s^{-1}, e.g. from 12.0 to 14.9 cm s^{-1}. The column at the right is the number of occurrences in each 10° direction band while the row at the bottom is the number of occurrences in each speed range.

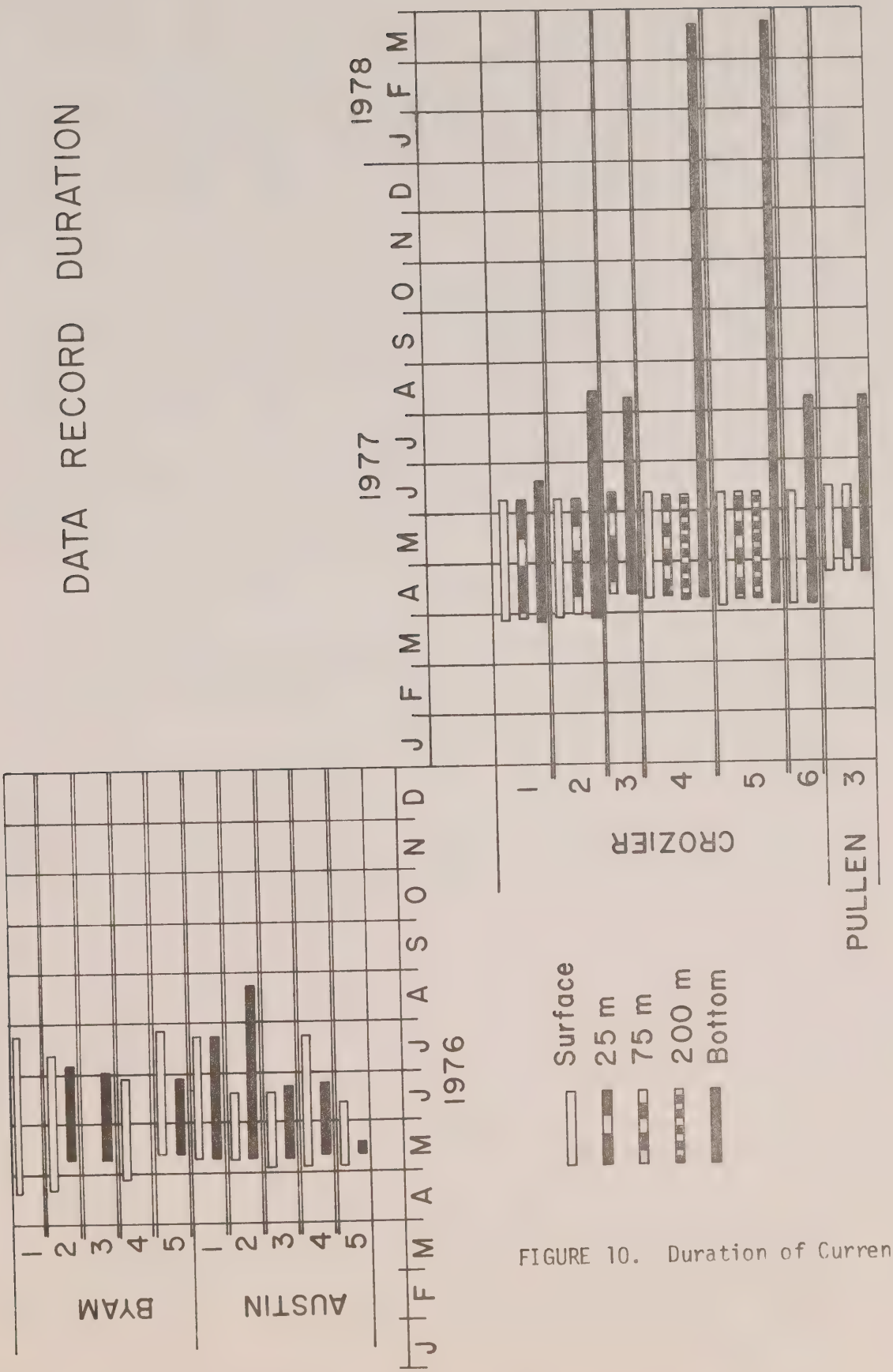


FIGURE 10. Duration of Current Records.

All the histograms exhibit a bimodal distribution in direction, generally oriented up and down channel. Such a distribution demonstrates frequent and consistent current reversals implying that the currents are dominated by tidal oscillations. Current speeds in Byam and Austin Channel are generally less than about 30 cm s^{-1} and in Crozier and Pullen Straits less than about 40 cm s^{-1}. Events where the hourly average currents substantially exceed these values occur in the data from Byam 2T where speeds up to 75 cm s^{-1} were recorded and Pullen 3B where one 50 cm s^{-1} event was registered.

Auto-spectra of the along-channel and cross-channel velocity components were computed to ascertain the distribution of kinetic energy with frequency. These spectra confirmed our initial speculations that the current records were dominated by tidal oscillations primarily along the channel axes since the along-channel spectra are more energetic in the tidal bands than the cross-channel spectra. Figure 11 is the auto spectrum from current meter C5 (75m depth). The axes are both linearly scaled to aid in recognition of the distribution of kinetic energy which is simply the area under the curve. All the resolvable oscillations are contained in the frequencies less than 6 cycles per day. Above this frequency the least count noise due to the finite digitization in speed inherent in the current meter, exceeds the signal:

$$\text{least count noise} = \left(\frac{\text{PREC}}{2}\right)^2 \frac{1}{\Delta f}$$

Here PREC is the precision of the speed values and Δf is the frequency step over which the spectral estimates are averaged. For these spectra we used Δf of 0.343 cpd and the precision of the Aanderaa Curent meter is $\pm$ 0.5 cm s^{-1} so that least count noise

$$= \left(\frac{0.5 \text{ cm s}^{-1}}{2}\right)^2 \frac{1}{.343 \text{ cpd}}$$

$$= 1.9 \times 10^{-1} \text{ (cm s}^{-1}\text{)}^2 \text{ d}$$

We shall therefore, in the following sections, limit our discussion to the characteristic of the mean flow, long period and tidal oscillations.

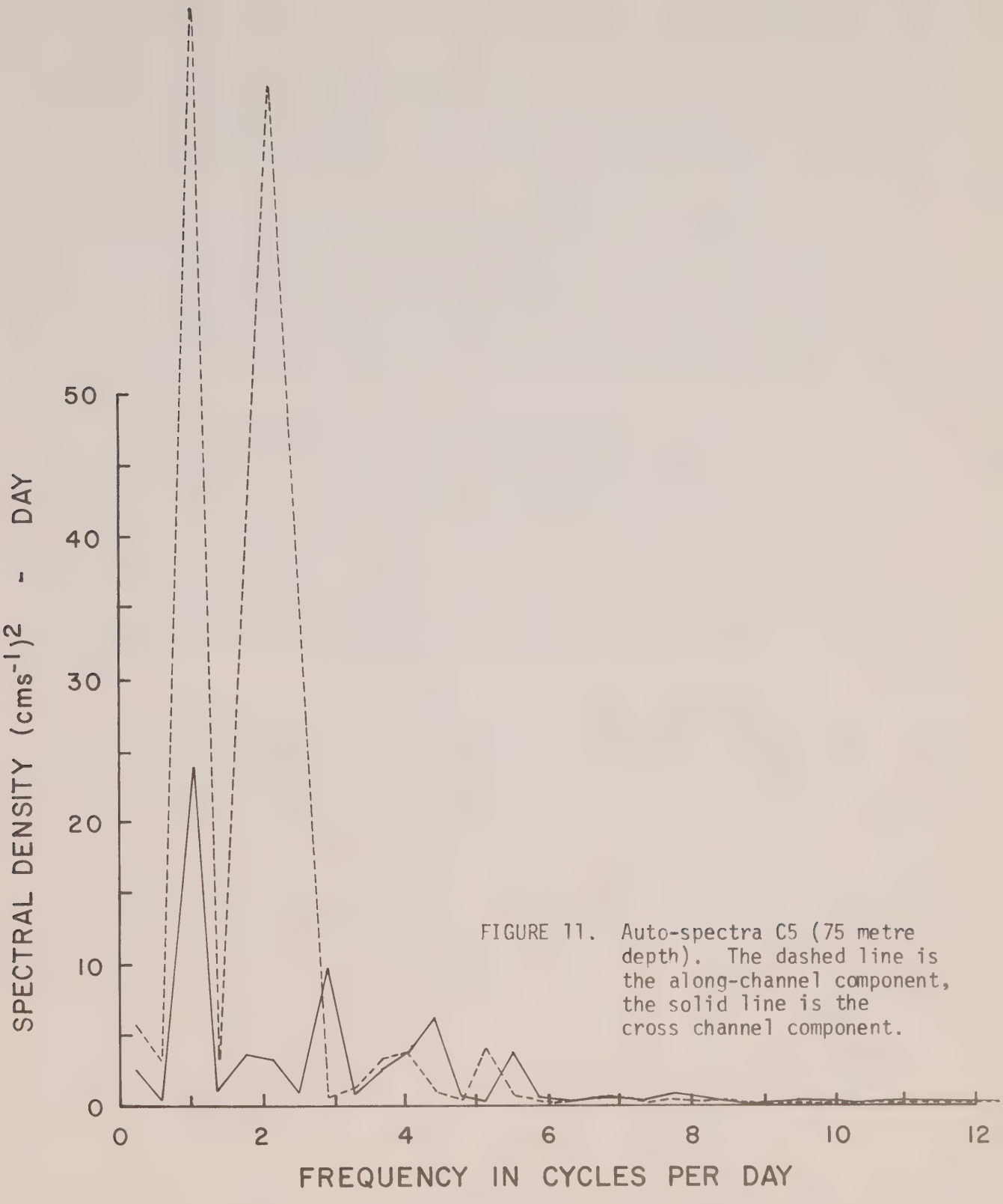


FIGURE 11. Auto-spectra C5 (75 metre depth). The dashed line is the along-channel component, the solid line is the cross channel component.

2. MEAN FLOW

The vector mean velocities at each current meter were determined over the entire length of each record. For most of the current records this constitutes an average value during the 3 or 4 months of late spring and early summer. We comment on the results of such averages while attaching no "annual mean" significance to them.

In Byam and Austin Channels the current meters were either suspended with the rotors 0.15 metres below the ice or 2 metres above the bottom. The current meters, at surface and bottom locations, due to their proximities to the boundaries, do not supply data which are necessarily representative of the free stream flow. We feel that great caution must be observed in trying to interpret these current records, nevertheless we proceed to do so after a brief discussion of some of the pitfalls.

a) The nature of current measurements made within the boundary layer

In a turbulent rotating ocean the boundary layer is composed of two parts. The inner boundary layer is the logarithmic or constant flux layer where the familar law of the wall applies:

$$u = \frac{u_*}{k} \ln \frac{z}{z_o} \qquad 2.1$$

where u is the fluid velocity, u_* is the friction velocity, k is Von Karman's constant, z is the distance from the boundary and z_o represents a roughness length. u_* is representative of the stress at the boundary and is equal to $\sqrt{\tau/\rho}$ where τ is the boundary stress.

The outer boundary layer or Ekman layer is thought to begin at a distance of $fz/u_* = 0.03$ in the atmosphere (Tennekes, 1973) where f is the Coriolis parameter. This corresponds to a distance of about 2 m from the boundary in the ocean. At this distance some sort of planetary boundary layer dynamics hold which include the effect of the earth's rotation.

In Ekman's original solution, the velocity at the boundary is zero and asymptotically approaches the free stream or geostrophic velocity away from the boundary. The velocity in the boundary decreases with proximity to the boundary so that the Coriolis force decreases. This causes a modification of the flow direction from perpendicular to the pressure gradient (geostrophic balance) to more nearly down the pressure gradient. The equations used to arrive at this solution are

$$-fv = A_z \frac{\partial^2 u}{\partial z^2} \qquad 2.2$$

$$fu = A_z \frac{\partial^2 v}{\partial z^2} - \frac{1}{\rho} \frac{\partial p}{\partial y} \qquad 2.3$$

where u is the eastward (x) and v is the northward (y) component of velocity and A_z is the eddy viscosity.

If the fluid outside the boundary layer is in geostrophic equilibrium then $f u_g = \frac{-1}{\rho} \frac{\partial P}{\partial y}$ and the solution for the velocity in the boundary layer can be written

$$u = u_g \ (1 - e^{-az} \cos az) \qquad 2.4$$

$$v = u_g \ e^{-az} \sin az \qquad 2.5$$

where $a = \sqrt{f/2A_z}$ and u_g is the easterly flowing geostrophic velocity.

A hydograph of the velocity vectors within the Ekman boundary layer is shown in Figure 12. The velocity vector veers to the left as well as decreasing in magnitude with decreasing distance from the boundary. At the boundary, or the inner limit of the Ekman layer, the angle of veering is 45° to the left of the geostrophic flow. The horizontal mass transport over the depth of the Ekman layer has a component perpendicular to the geostrophic flow.

This lateral transport must be compensated by a return flow in a laterally bounded ocean. In the case of wind driven ocean currents, the lateral (or cross isobar) transport in the atmosphere-ocean Ekman layer is compensated by an opposite transport in the bottom boundary layer. However, in a sea covered with land-fast ice, the Ekman veering is in the same (down pressure gradient) direction in both the surface and bottom Ekman layers, necessitating a return flow at some intermediate depth. The presence of the ice cover, therefore, changes the usual single vortex secondary circulation to a twin vortex secondary circulation with the vortex axes directed along the channel.

Since the surface and bottom current meters were positioned either within the inner boundary layer or in the inner reaches of the planetary boundary layer, we expect them to sense the full effect of the Ekman veering. The mean current vector should be oriented 45° to the left of the channel axis or equivalently with the direction of the mean flow away from the boundaries. The mean current vectors are shown in Figures 13 and 14. The Byam-Austin vectors can only be compared with the orientation of the channels as measured from charts, see Figure 2. However, the mean vectors from Crozier and Pullen Straits exhibit no consistent change in direction between mid-depths (200 and 75 m) and the surface and bottom. In no case can the near-boundary mean vectors be thought of as displaying a 45° rotation to the left of the mean flow.

Although there is some ambiguity due to an estuarine-like flow, in general the current vectors from Crozier and Pullen Straits show only a very slight decrease in magnitude between mid depth and the surface and bottom meters. This is especially clear at Crozier 1 and Crozier 5 where no apparent variation in the magnitude of the mean vector is measured between surface and mid depth.

The dynamics of the boundary layers in these channels clearly do not correspond to the classical Ekman formulation. Since the current measurements from Byam and Austin Channels have all been made within the boundary layers we seek further for applicable models, the use of which might permit extrapolation of current measurements to the "free stream".

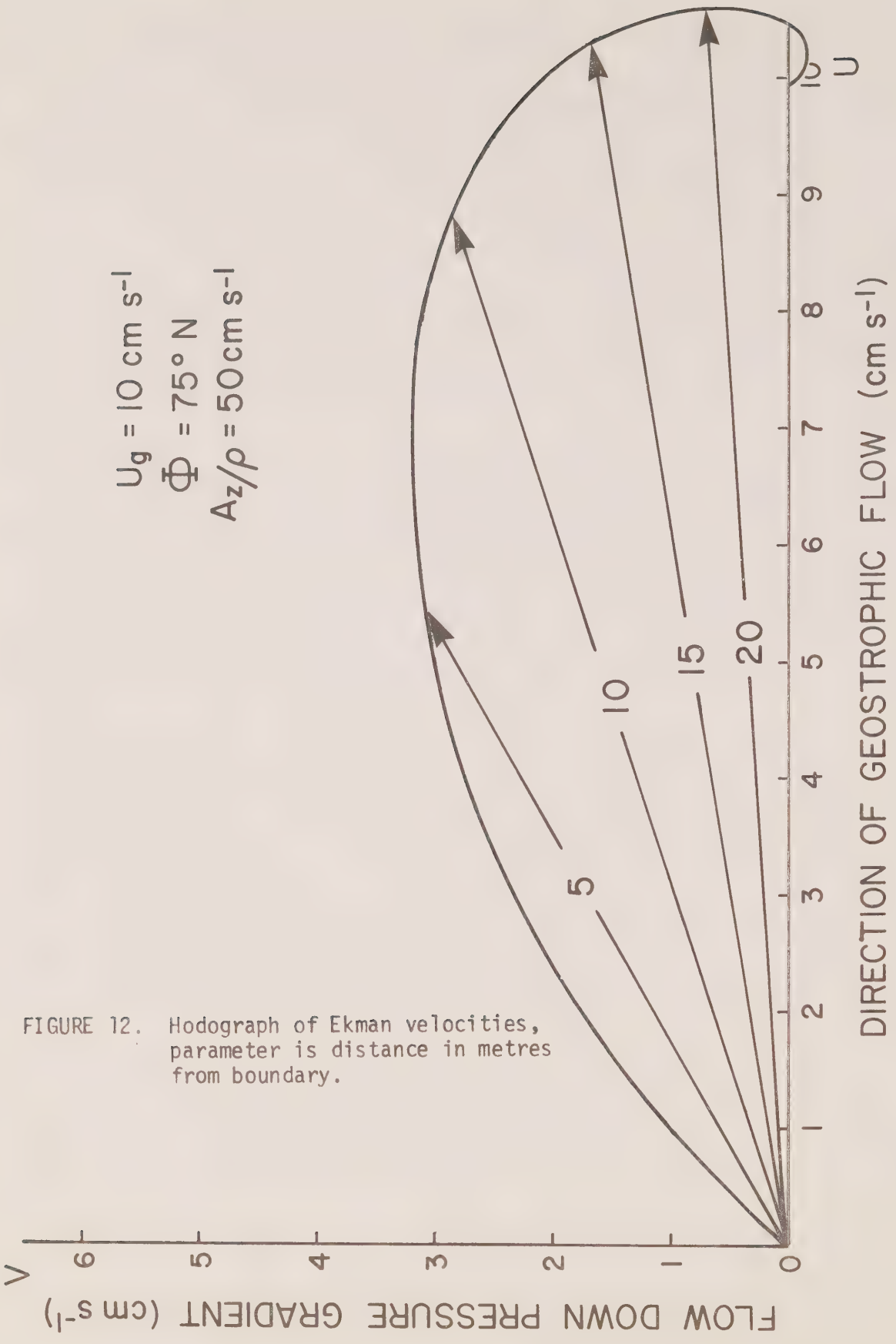


FIGURE 12. Hodograph of Ekman velocities, parameter is distance in metres from boundary.

The Ekman formulation is based on several assumptions: steady flow, fully developed boundary layer justifying the neglect of the non-linear accelerations, a constant eddy viscosity and a homogeneous or gravitationally neutrally stable fluid. Recently, several authors have examined planetary boundary layers including one or more of the effects which Ekman neglected. Madsen (1977) used linear equations of motion but introduced an eddy viscosity which increased linearly with distance from the boundary. In his steady state solution he found a turning angle of about 10° and a much larger velocity shear than predicted by the constant eddy viscosity formulation. We can interpret Madsen's results (which were developed for the wind driven planetary boundary layer) to imply that the current magnitude is roughly 2/3 that of the free stream flow at a distance of about $0.01\ ku_*/f$ from the boundary. Typical values of u_* are in the neighbourhood of 0.5 to 1.0 cms $^{-1}$ so that the distance at which 2/3 of the free stream speed is achieved at 75° N. is roughly 13 to 28 cm from the boundary.

A second possible explanation for the absence of the Ekman layer beneath the ice lies in the contribution of buoyancy or convective effects to the turbulent kinetic energy of the boundary layer. Convection in the ice-water boundary layer is driven by the rejection of salt from growing sea ice. The convectively driven vertical motions work, in effect, to enhance the viscosity by augmenting momentum exchange between the sea and the ice. Deardorff (1972) has shown that the region over which the buoyancy dominates the mean shear contribution to the turbulent kinetic energy can be expressed in terms of the Obukhov length, L.

$$L = \frac{\rho_o u_*^3}{gk \langle \rho' w' \rangle} \qquad 2.6$$

where ρ_o = mean water density in the boundary layer

u_* = friction velocity

g = acceleration of gravity

k = Von Karman's constant

ρ' = fluctuations in fluid density

w' = fluctuations in vertical velocity

and $\langle \rho' w' \rangle$ = vertical density flux.

The dynamics of a neutrally stable Ekman layer were shown to be inapplicable for values of $Z_i/L < -1.5$ where Z_i is the depth of the pycnocline. McPhee and Smith (1975) have shown that the vertical density flux due to ice growth can be expressed as

$$\langle \rho' w' \rangle_{surface} = \rho_{ice} (\Delta S)\, d/10^3 \qquad 2.7$$

where ρ_{ice} is the ice density, ΔS is the salinity difference in $^{o}/_{oo}$ between the ice and the water and d is the growth rate expressed in cm s^{-1}. The ice growth rate may, in turn, be estimated using the heat flow equation

$$\frac{dq}{dt} = \rho_i \, C_p \, k \, \frac{dT}{dZ} \qquad 2.8$$

where $\rho_i \, C_p \, k$ = the thermal conductivity

$\frac{dq}{dt}$ = the heat flux

$\frac{dT}{dZ}$ = the temperature gradient within the sea ice

The ice growth rate is then

$$d = \frac{C_p \, k \, \Delta T}{L_a \, \Delta Z} \qquad 2.9$$

where L_a is the latent heat of fusion of sea ice. A rough calculation for a 1 m thick ice sheet and a 20°C temperature difference yields an ice growth rate of about 1.2×10^{-5} cm s^{-1}.

Finally, the ratio Z_i/L may be expressed in terms of the depth of the pycnocline and the friction velocity by using 2.6, 2.7 and 2.9,

$$Z_i/L = \left(\frac{Z_i}{u_*^3} \right) \quad (1.12 \times 10^{-4} \text{ cm}^2 \text{ s}^{-3}). \qquad 2.10$$

For a pycnocline depth of 30 metres and a friction velocity of 0.5 cm s^{-1}

$$Z_i/L = -2.7 \quad < -1.5$$

Deardorff showed that the lateral component of velocity in a convective planetary boundary layer is an order of magnitude smaller at $Z_i/L = -4.5$ than in the neutral case. In addition, the shear is confined to the region within 1/10 of the pycnocline depth from the boundary rather than 1/2 the pycnocline depth as in the neutrally stable case. Convection due to sea ice growth therefore may also, potentially, minimize the boundary effects under the ice.

In summary, we are quite simply too ignorant of the dynamics which apply in the surface and bottom boundary layers to attempt any sort of extrapolation to the free stream. We therefore report all current measurements, volume transports and tidal streams from these meters without modification; we assume that the boundary layer is infinitesmal, keeping in mind that this will tend to lower our transport estimates and have an adverse effect on the computation of internal tide modes.

b) Mean Vectors

The data from the bottom current meters in Byam and Austin Channels were telemetered by an acoustic link to a surface unit and then transmitted to a shore based receiving station. The completeness of the record suffered, especially in the acoustic transmission, so that data recovery from this

system ranged between 97% and about 50%. We have assumed that the gaps in the records are more or less random and have computed mean flows from these incomplete records. All the other current data were recovered from the internally recording Aanderaa current meters.

Although the current records are dominated by tidal oscillations, by averaging over many tidal cycles, the mean flow can be ascertained. The mean current vectors for the full lengths of the records were computed and are displayed in Figures 13 and 14. The channel cross sections are through the current meter moorings which lie in a straight line, and the tail of each vector is located at the position where the measurement was made. With the notable exception of Crozier West, the transverse or cross-channel variation in the direction of mean currents is slight. What are probably effects of very shallow water are noticeable at the edges of Byam Channel where the currents are directed across the channel.

In both Byam and Austin Channels, the surface currents appear to be more nearly oriented along the channel axis (as indicated by the double-headed orientation arrow) than the bottom currents. The Crozier Strait West vectors imply a relatively strong southward flow on the western side and a weak northeast flow on the eastern side. There is very little vertical shear noticeable. Crozier Strait East exhibits a pronounced vertical shear in the water column with currents below about 150 m flowing northward. The one mooring in Pullen Strait showed flow at nearly right angles to the channel axis which implied there is very little net mass flux through this strait.

The most revealing current records are those from Crozier Strait East. Here the general southward flow through the Arctic Archipelago is reflected in the surface currents while the weaker northward currents nearer the bottom likely constitute a return flow of estuarine nature. This circulation is probably caused by an effective sill depth of between 100 and 150 metres. Figure 4 is a north-south section through McDougall Sound and Crozier Strait. The north-south components of the current vectors from site C5 are drawn and illustrate how the bottom topography to the north of Crozier Strait limits the southward flow. We do not have enough hydrographic data to address the possibility that the northward near-bottom flow is a return flow driven by entrainment of deeper water into the southward flowing upper layer. In any case the effective sill depth between Cornwallis and Bathurst Islands appears to be about 150 metres.

The vertical shear present in the Crozier East currents were compared with the geostrophic shear due to baroclinicity or the slope of the isopycnal surfaces. It is the geostrophic shear integrated from a "level of no motion" which is the classical method of measuring ocean currents. The first equation of motion assuming steady flow, insignificant non-linear accelerations and frictionless flow is

$$fv = \frac{1}{\rho} \frac{\partial p}{\partial x} \qquad 2.11$$

where f is the coriolis parameter, V is the northward velocity component, ρ is the mean density, and $\partial p/\partial x$ is the west to east pressure gradient. If

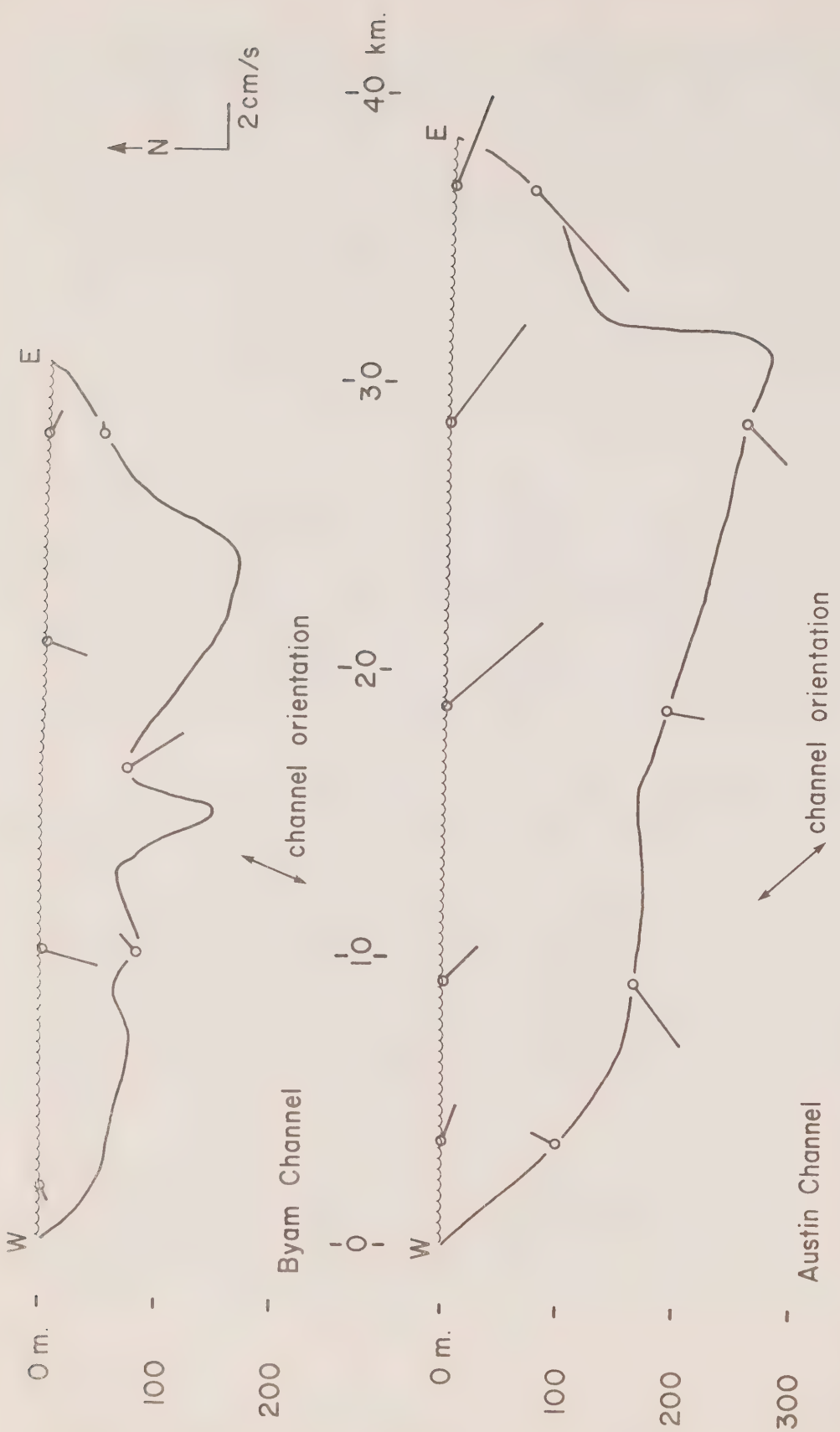


FIGURE 13. Mean Vectors, Byam and Austin Channels.

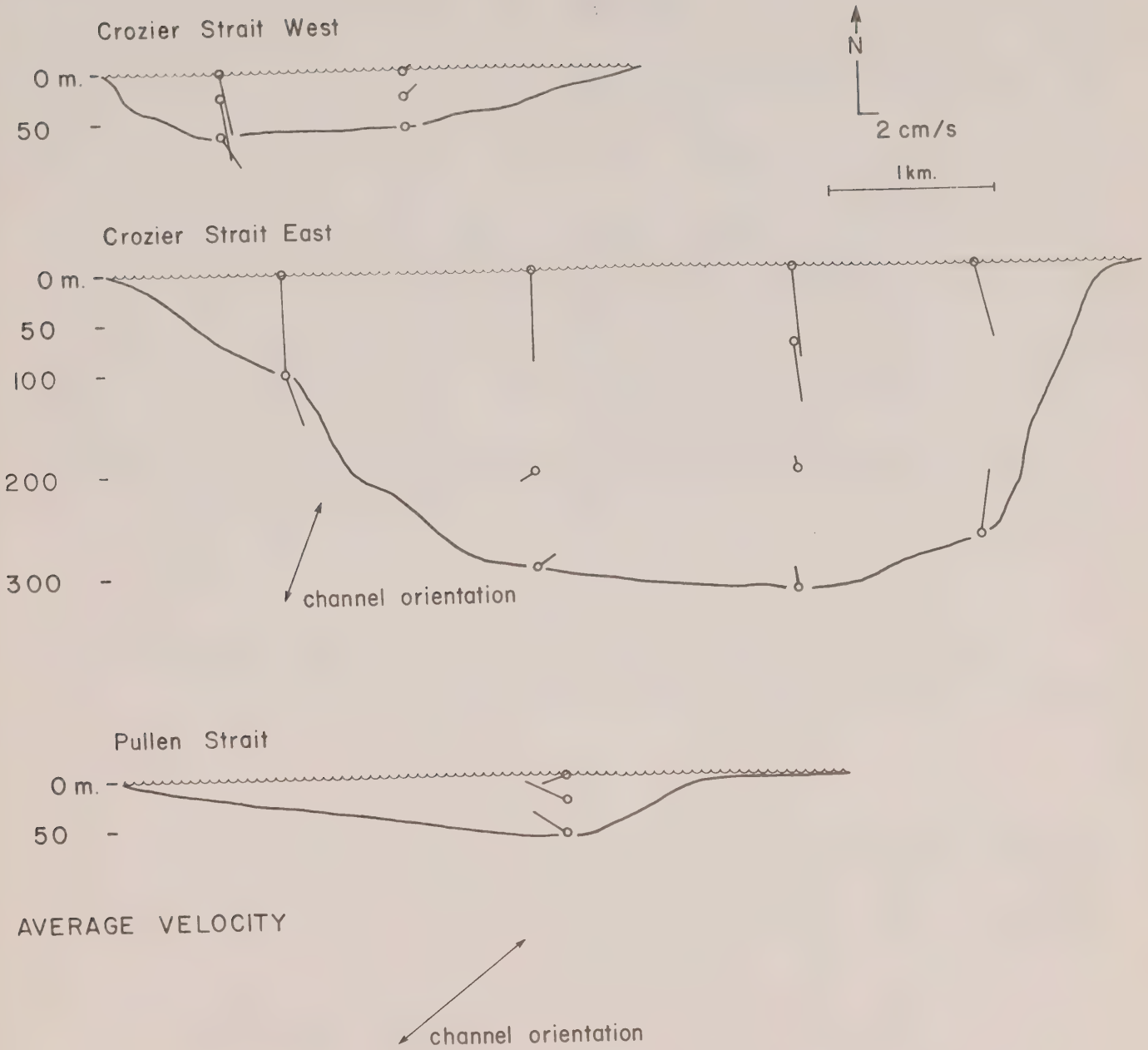


FIGURE 14. Mean Vectors, Crozier and Pullen Straits.

2.11 is differentiated with respect to z,

$$f\rho \frac{\partial v}{\partial z} + fv \frac{\partial \rho}{\partial z} = \frac{\partial^2 p}{\partial x \partial z} \qquad 2.12$$

The hydrostatic or 3rd equation of motion is

$$\frac{\partial p}{\partial z} = -\rho g \qquad 2.13$$

where z is vertically up and g is the acceleration of gravity which when inserted in 2.12 yields

$$f\rho \frac{\partial v}{\partial z} + fv \frac{\partial \rho}{\partial z} = -g \frac{\partial \rho}{\partial x} \qquad 2.14$$

which is the first thermal wind equation.

The second term in 2.14 is two to three orders of magnitude smaller than the first which can be demonstrated by inserting typical values:

$$f\rho \frac{\partial v}{\partial z} \Big/ fv \frac{\partial \rho}{\partial z} = \frac{\frac{1}{v}\frac{\partial v}{oz}}{\frac{1}{\rho}\frac{\partial \rho}{\partial z}} \simeq \frac{\Delta v/v}{\Delta \rho/\rho}$$

A 50% to 100% change in velocity is usually present over the depth of the water column while the change in density is usually less than 1%. Neglect of the second term in 2.14 is, therefore justified, so that

$$\frac{\partial v}{oz} = -\frac{g}{\rho f}\frac{\partial \rho}{\partial x} \qquad 2.15$$

2.15 defines the geostrophic shear in terms of the cross-stream gradient of density. Comparison of the shear computed from CTD measurements across Crozier Strait with the measured mean shear showed that the mass field could account for only a few percent of the measured shear. This is due to the very weak vertical stratification caused by strong tidal currents. Weaker stratification necessitates more strongly sloping isopycnals to provide a given geostrophic shear. However the slope of the isopycnals is limited by a criterion of baroclinic stability so that the maximum geostrophic shear which will be computed is proportional to the vertical stratification. The classical geostrophic measurements are, therefore, of little use in this region of very weak stratification.

c) Transports

The components of the mean vectors parallel to the channel axes were computed in order to construct mean isotach cross sections for the computation of mean transports for the period April - June (shown in figures 15 and 16). The isotachs were constructed by linearly interpolating between

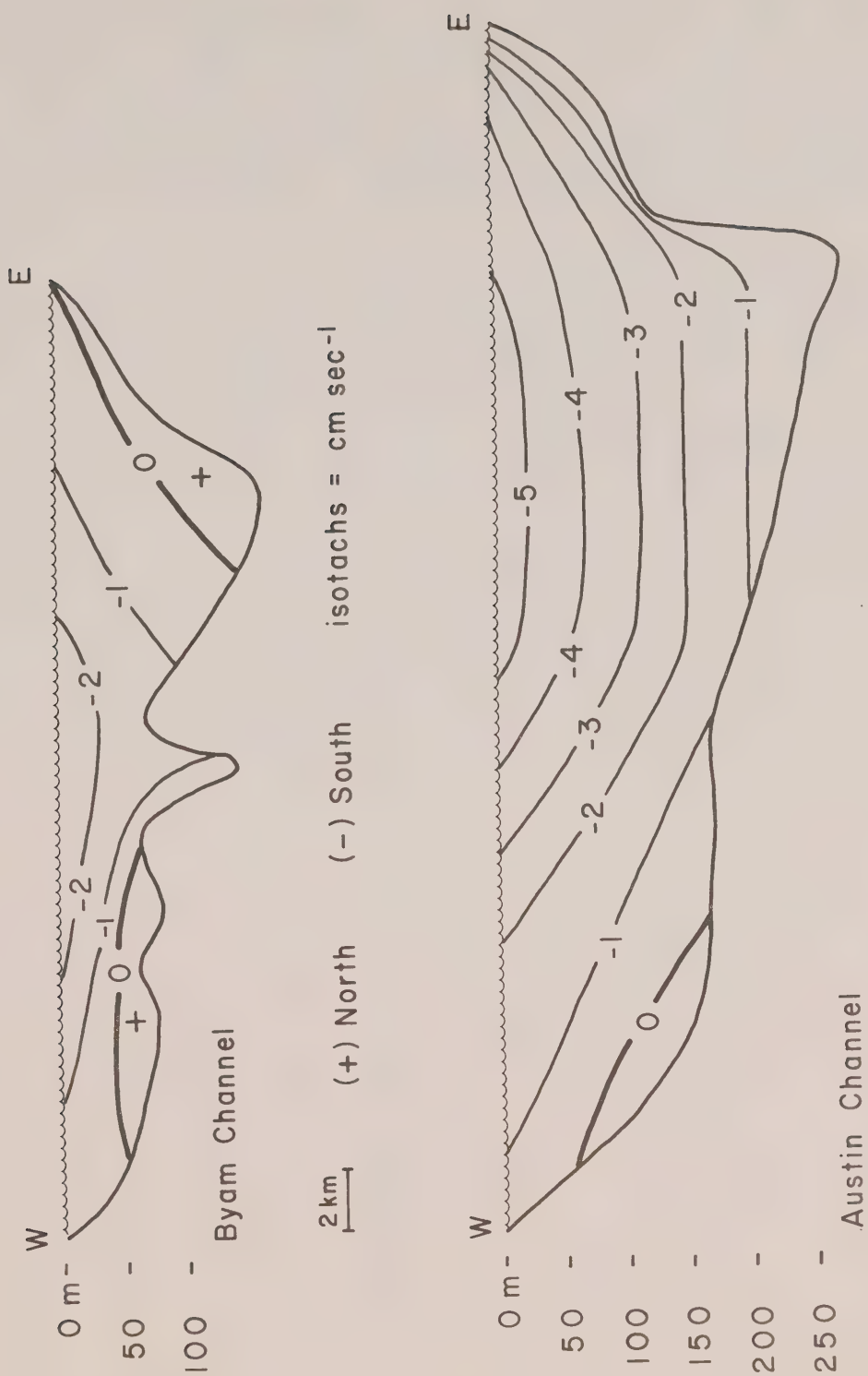


FIGURE 15. Isotachs, Byam and Austin Channels.

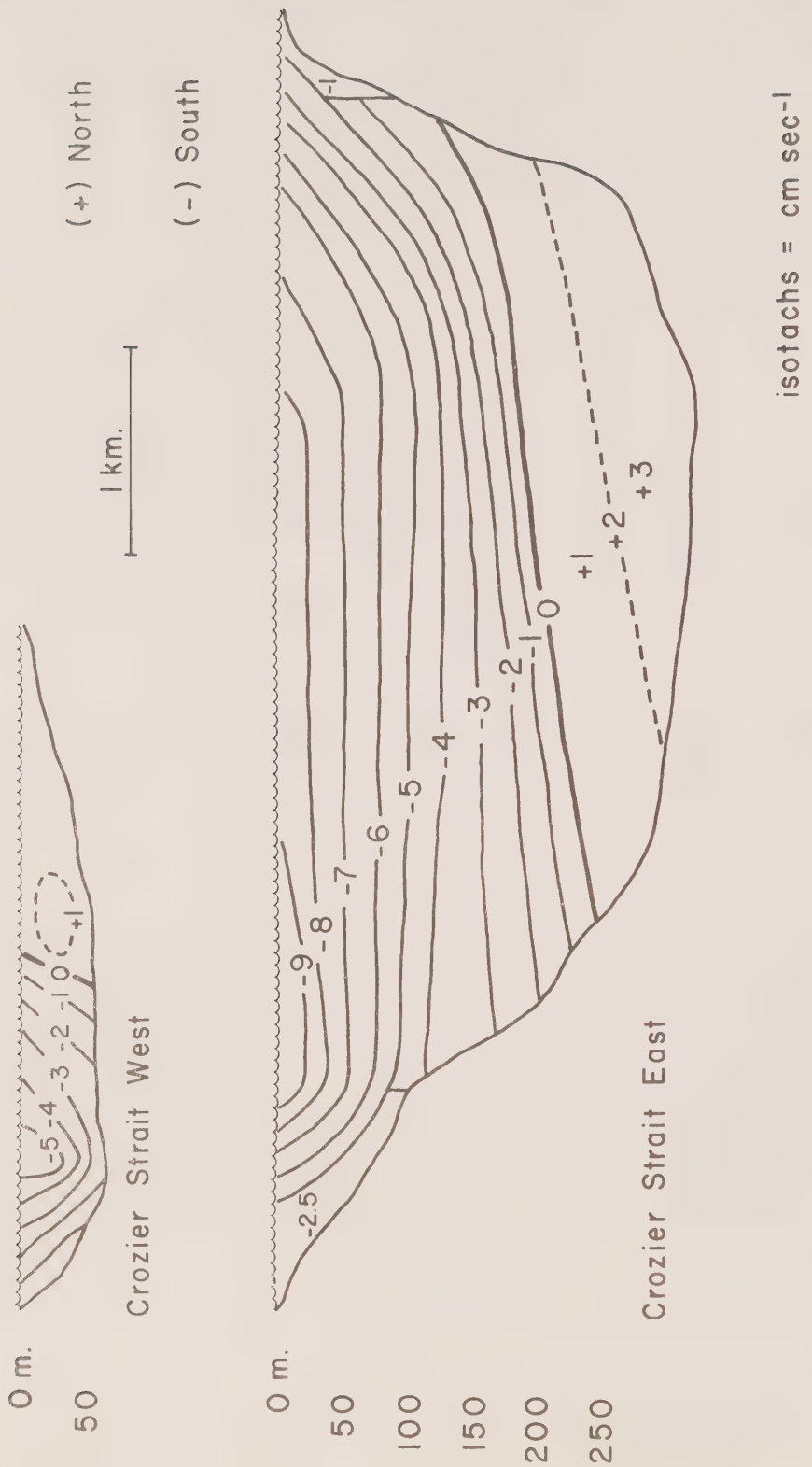


FIGURE 16. Isotachs, Crozier and Pullen Straits.

the current meter locations and the transports were computed by measuring the areas within the speed ranges. With the exception of Pullen Strait where the mean flow was directed nearly perpendicular to the channel axis, each of the channels is dominated by southward flow while areas of mean northward flow are never completely absent. Both channels in Crozier Strait have the southward flow concentrated toward the western shore as one would expect on a rotating earth. The Byam and Austin Channel records do not indicate such an effect, but the lack of completeness of these latter data must be borne in mind.

The transports estimated for the 5 channels are listed in Table 2. The estimates are based on the entire length of the current records which are usually about 2 or 3 months long. There are two current records which span nearly one year's operation: C4B and C5B. From these records (cf Figure 29) we can see that the flow in Crozier Strait is more energetic during the winter. We might, therefore, be justified in augmenting the transport estimates of Table 2, but we chose to limit our computation to the sampling time over which we have full coverage.

TABLE 2

VOLUME TRANSPORTS

Byam Channel	-1.95	$\times 10^4$	$m^3 s^{-1}$
Austin Channel	-14.03	$\times 10^4$	$m^3 s^{-1}$
Crozier Strait West	-0.20	$\times 10^4$	$m^3 s^{-1}$
Crozier Strait East	-4.23	$\times 10^4$	$m^3 s^{-1}$
Pullen Strait	-0.19	$\times 10^4$	$m^3 s^{-1}$

3. LONG PERIOD OSCILLATIONS

In this section we briefly deal with the observed current oscillations of greater than 24 hour period. Such oscillations are usually ascribed to meterological forcing planetary or topographic Rossby waves or a general seasonal or climatic cycle. Of particular interest in the examination of the long-period oscillations are the year-long current records made at sites C4 and C5 near the bottom.

Daily average current vectors were computed and plotted along a time axes (stick diagrams) for each of the current meter records. The daily vectors from Byam and Austin Channels are shown in Figures 17, 18, 19 and from Crozier and Pullen Straits in Figures 20 through 28. In these diagrams north is toward the top of the page and the length of the vector is proportional to the speed.

All the stick diagrams show that the daily average currents are generally in the direction of the mean currents (cf Figures 13, 14) but are modulated in amplitude over a period of 28-31 days as is the case for C4 surface or about 14 days as shown in the stick diagram from C3 bottom. These modulations might be ascribed to fortnightly and monthly tidal components, which when superimposed can account for differences in daily average current speeds of up to 11 cm s^{-1}, according to tidal analyses performed on the current records (see Section 4). However recent investigations (W. Crawford, pers. comm.) have shown that the fortnightly and longer tidal constituents require several years of records to be properly resolved. We therefore cannot dismiss these fluctuations as tidally induced, particularly in light of their varying phases.

a) Horizontal variations

The stick diagrams as well as the mean current vectors, for Byam and Austin Channels show that the currents in the centre of the channels are stronger than near the lateral boundaries. This effect is not present in Crozier Strait. The probable explanation for this difference in current fields lies in the differing channel shapes. Byam and Austin Channels are relatively shallower than Crozier Strait. Byam and Austin Channels also have gently sloping sides while the lateral boundaries of Crozier Strait are relatively steep. The surface current meters in Crozier Strait are, therefore further removed from both the lateral boundaries and the bottom. For a homogeneous fluid, the current speed will be greater in deeper water where the frictional effects of the bottom and ice cover must act over a deeper water column.

b) Vertical Variations

The currents are generally coherent in the vertical at each site where more than one current record was obtained. There does appear to be a change in flow regime at about 100-150 metre depth in Crozier Strait which is exemplified by Figure 24, the stick diagram from C5. Here the records at 75 metres and 200 metres depth appear to be well correlated if one considers a mean shear of about 6 cm s^{-1}/125 metres between the two current meters.

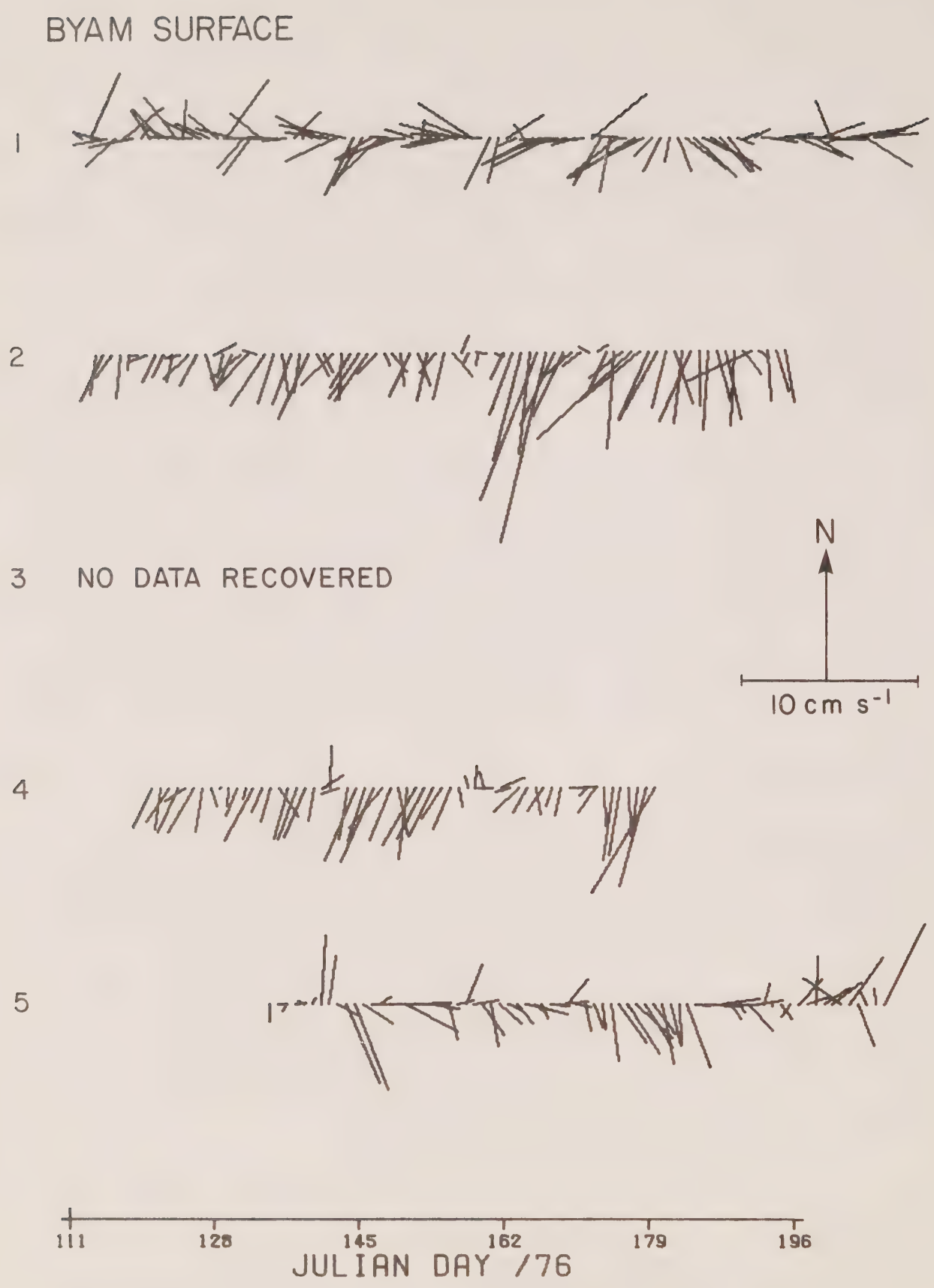


FIGURE 17. Daily average current vectors, Byam Channel surface.

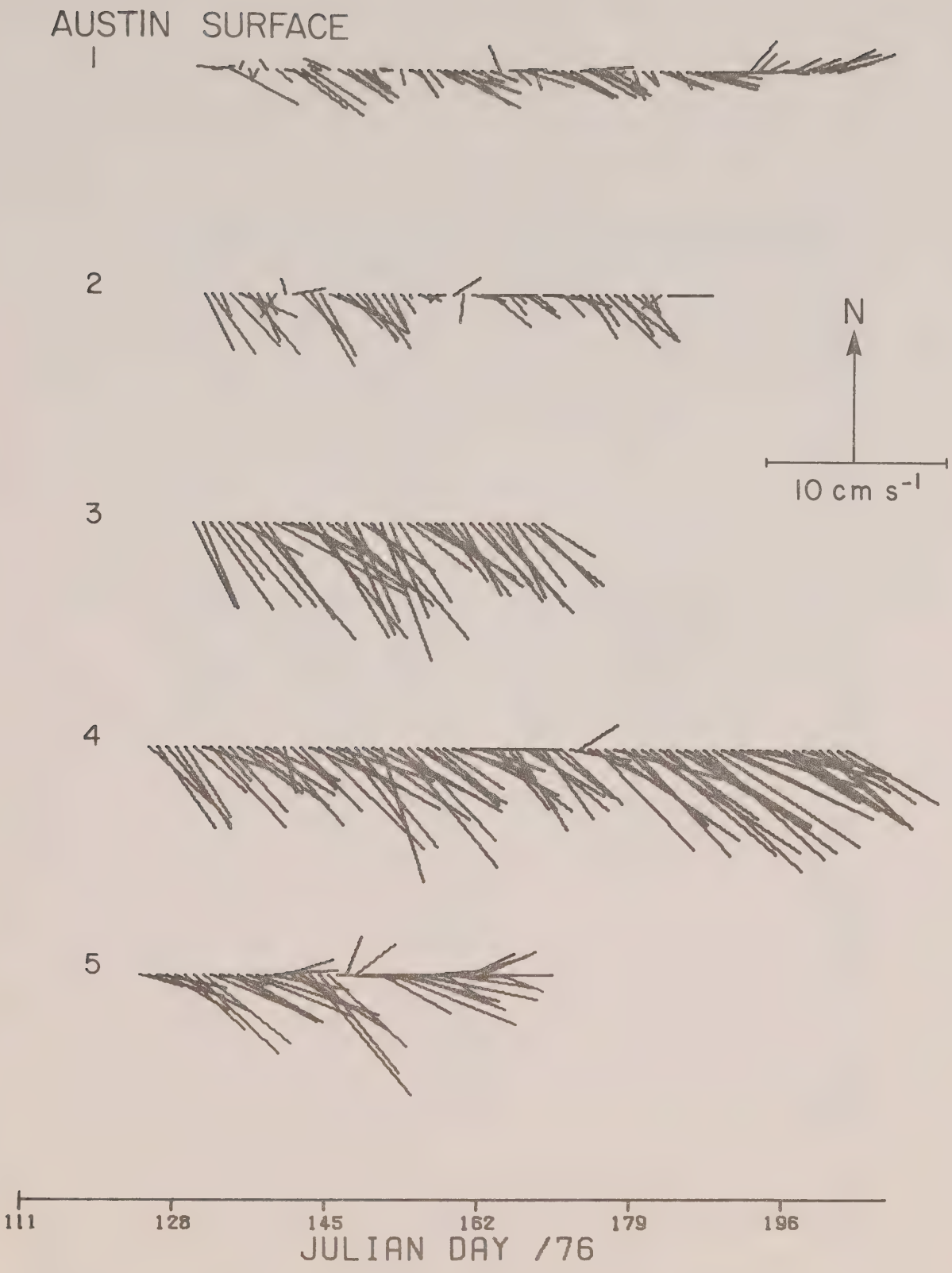


FIGURE 18. Daily average current vectors, Austin Channel surface.

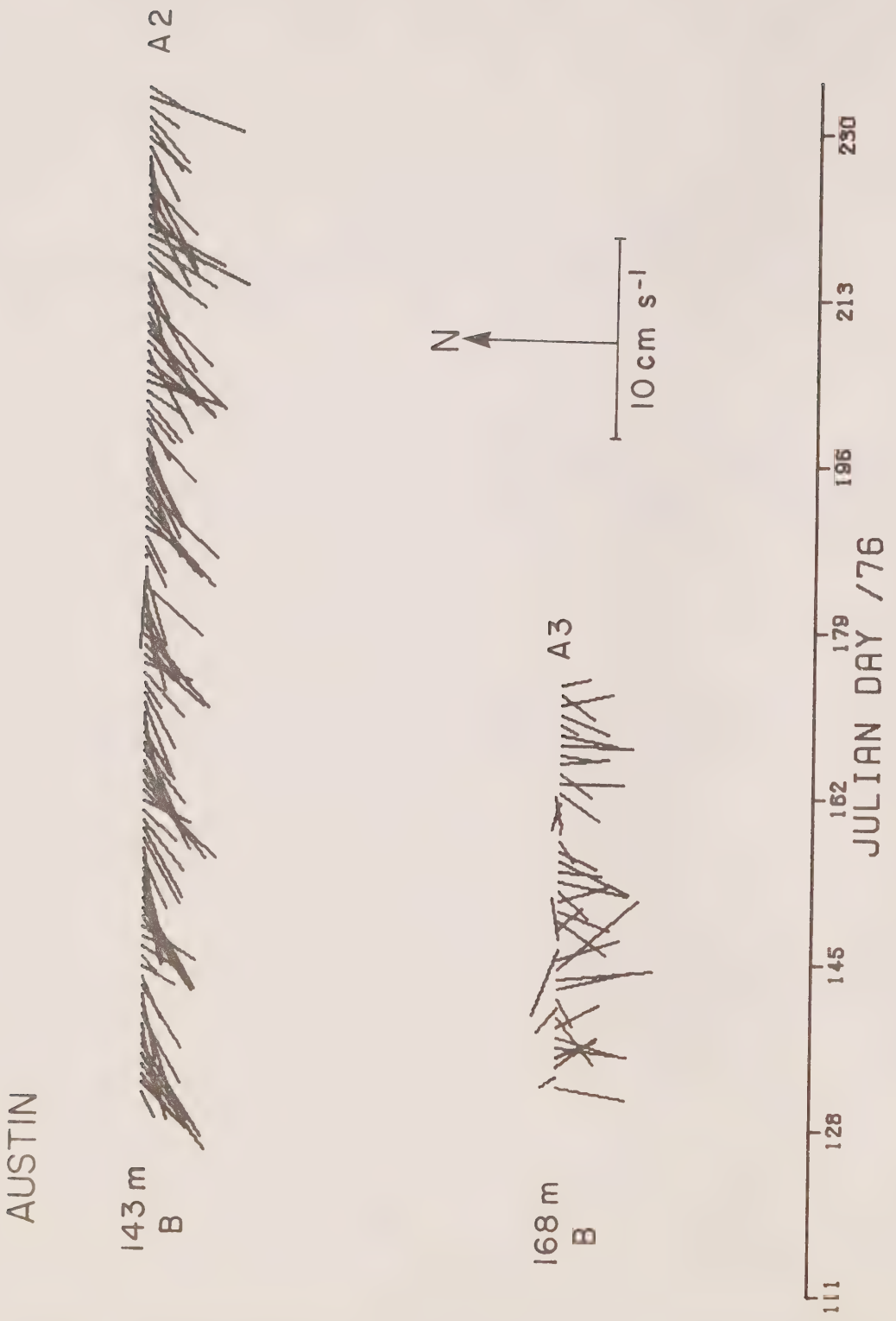


FIGURE 19. Daily average current vectors, Austin Channel, bottom.

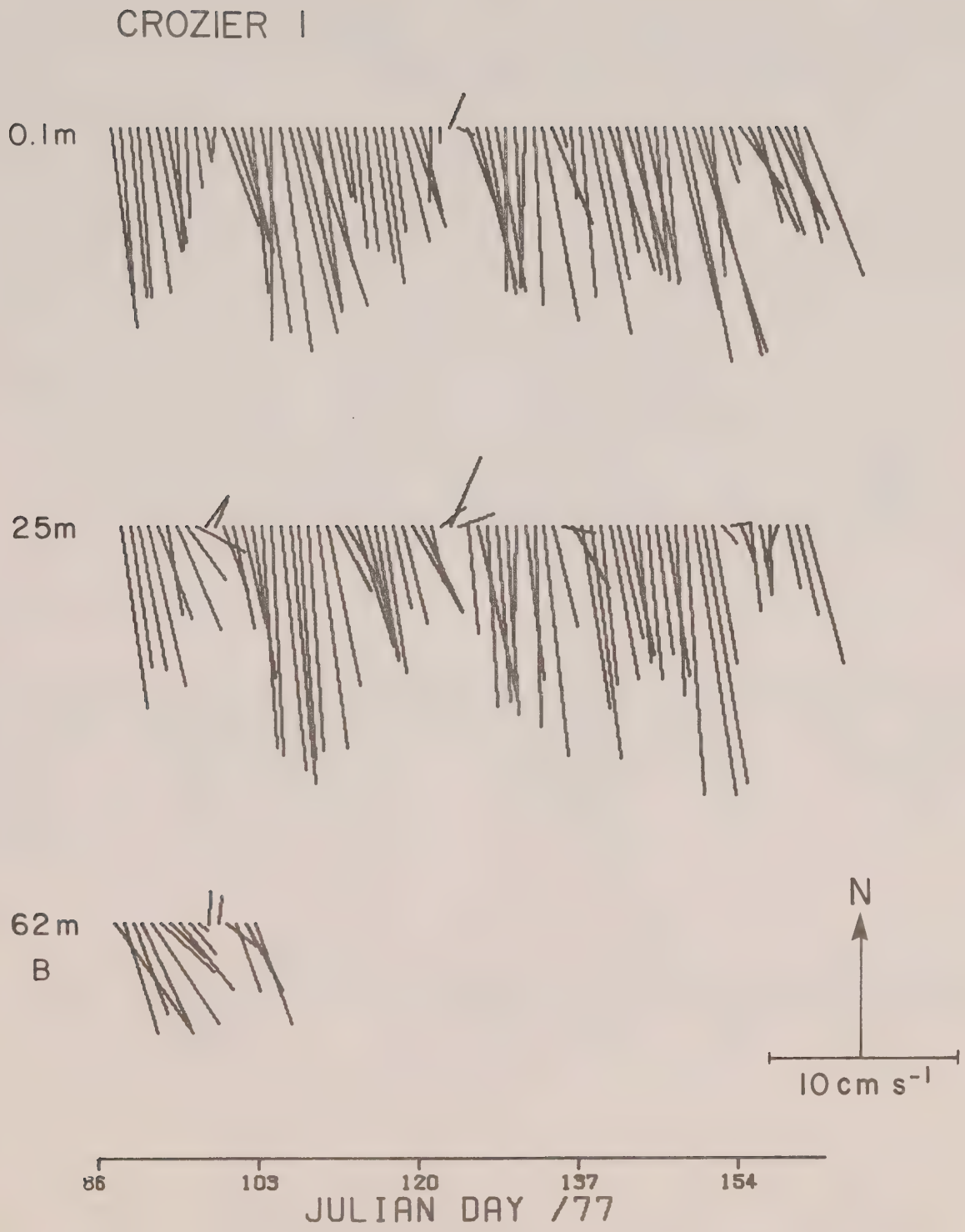


FIGURE 20. Daily average current vectors, Crozier Strait, site 1.

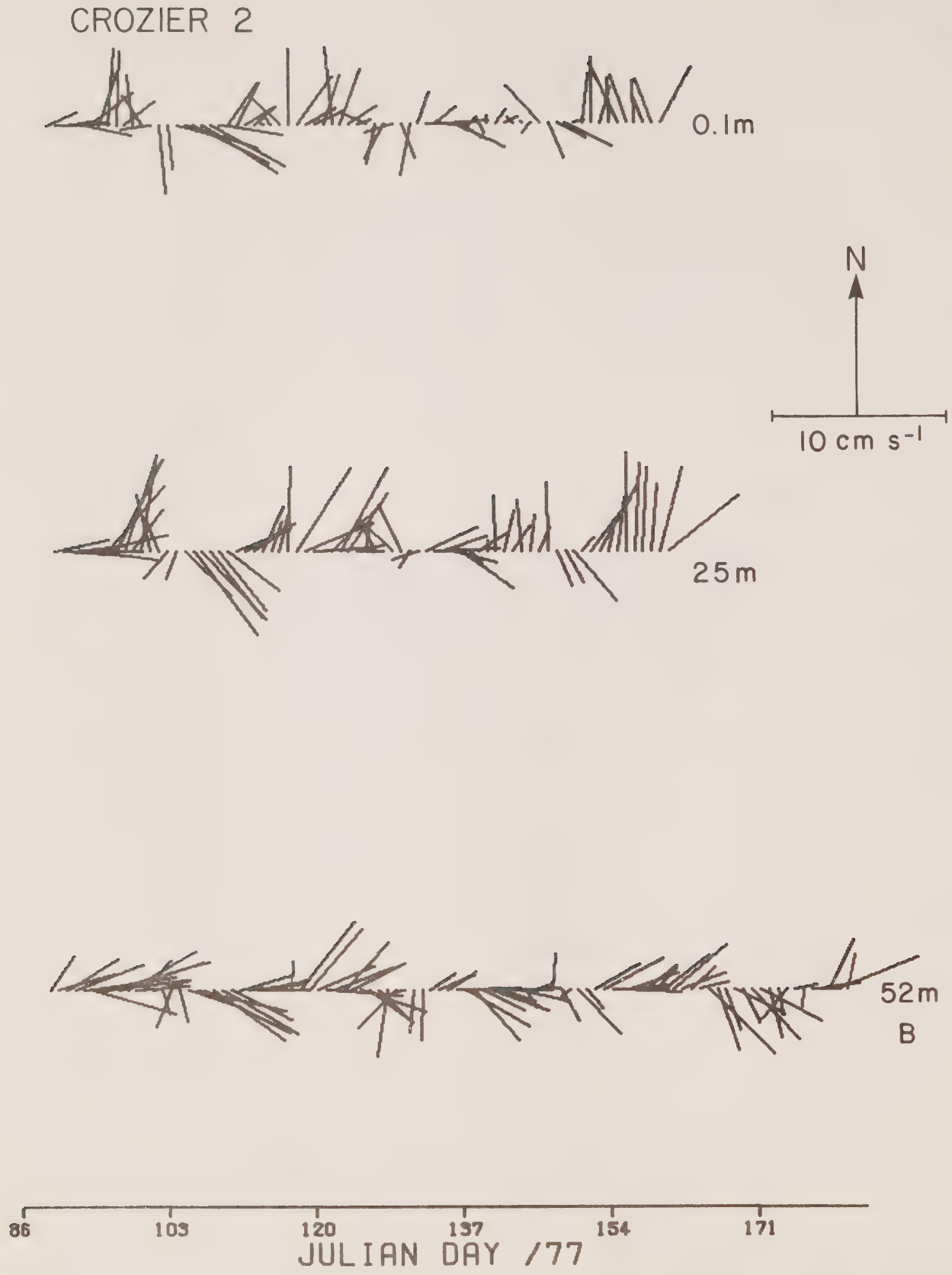


FIGURE 21. Daily average current vectors, Crozier Strait, site 2.

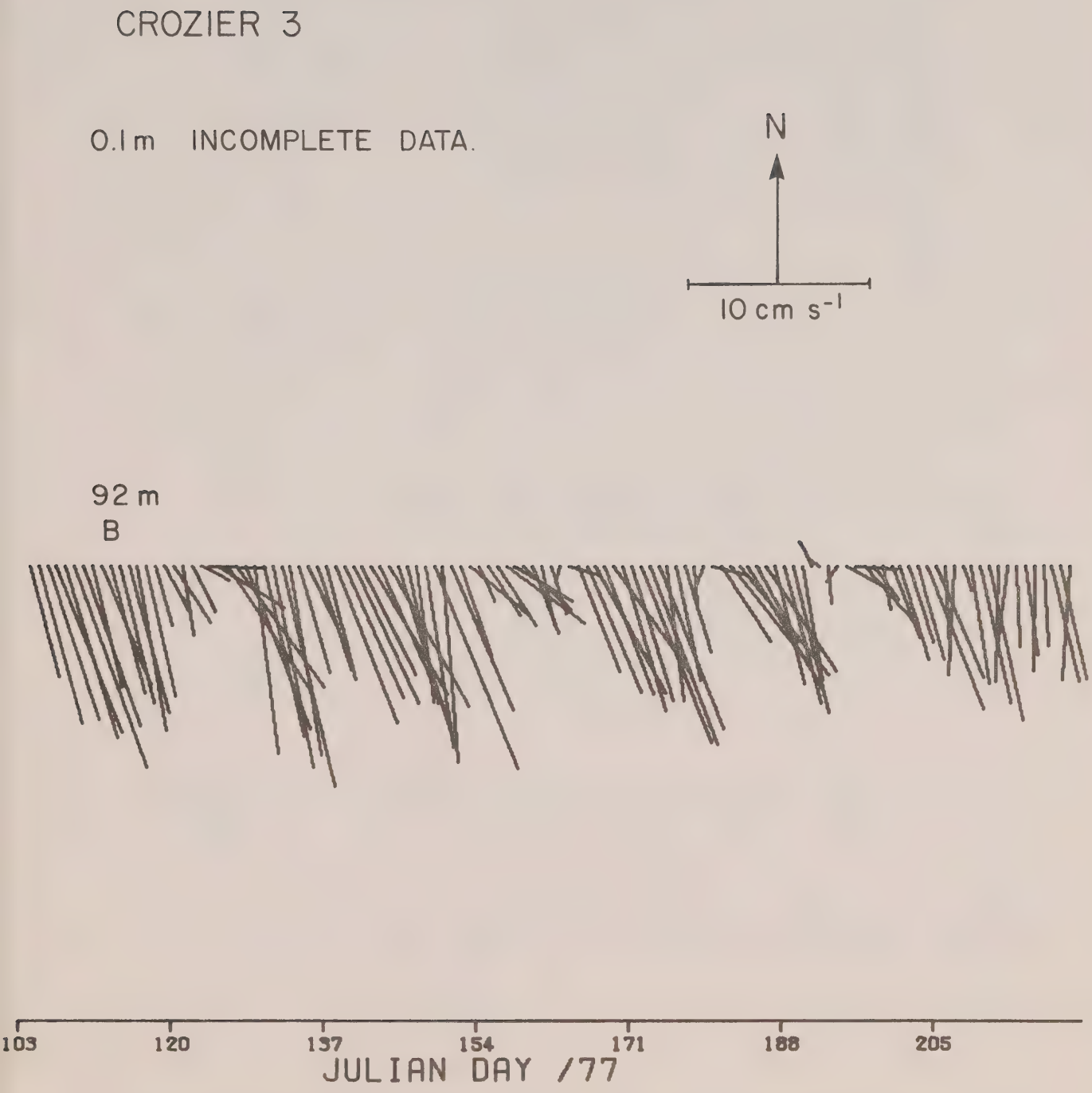


FIGURE 22. Daily average current vectors, Crozier Strait, site 3.

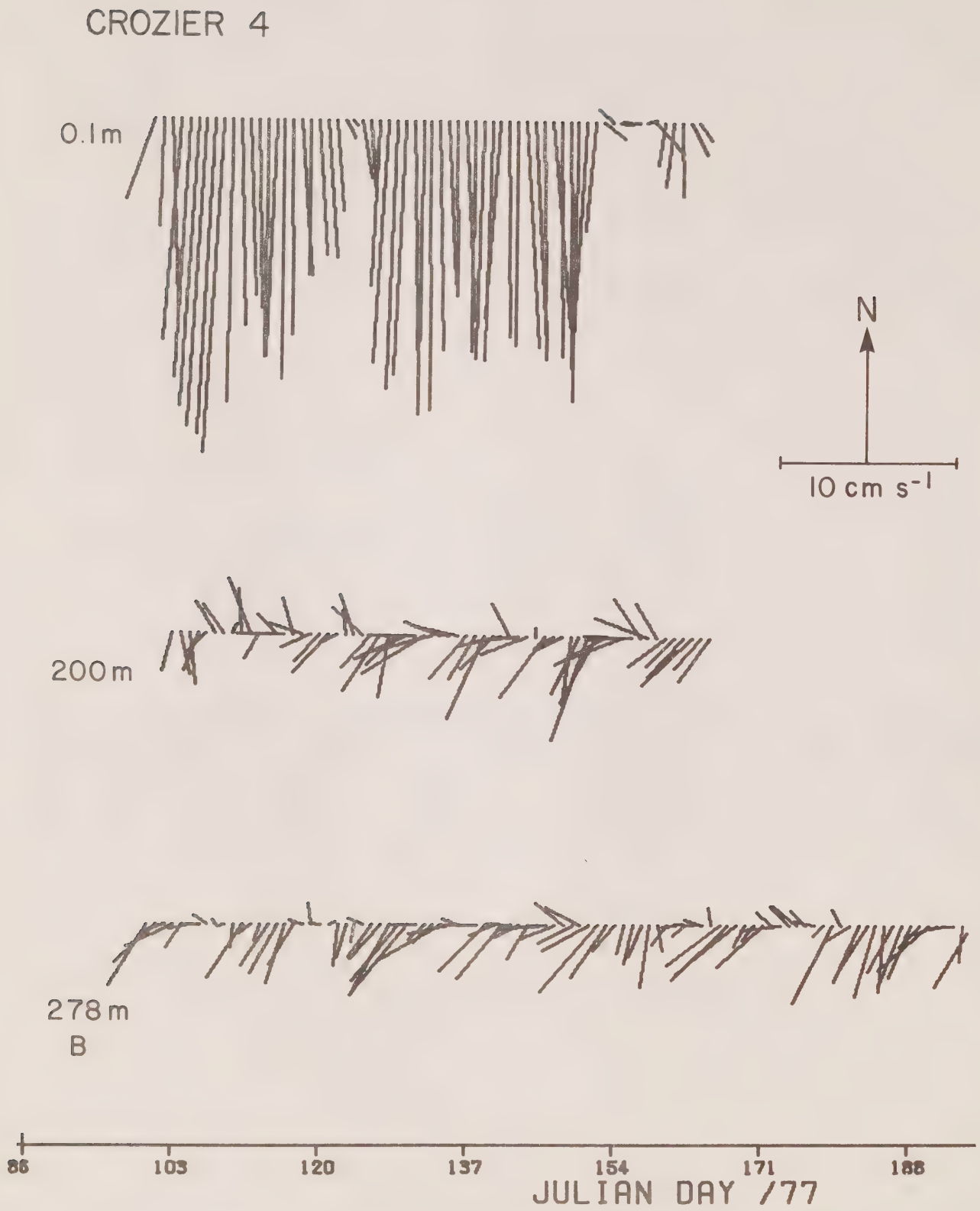


FIGURE 23. Daily average current vectors, Crozier Straite, site 4.

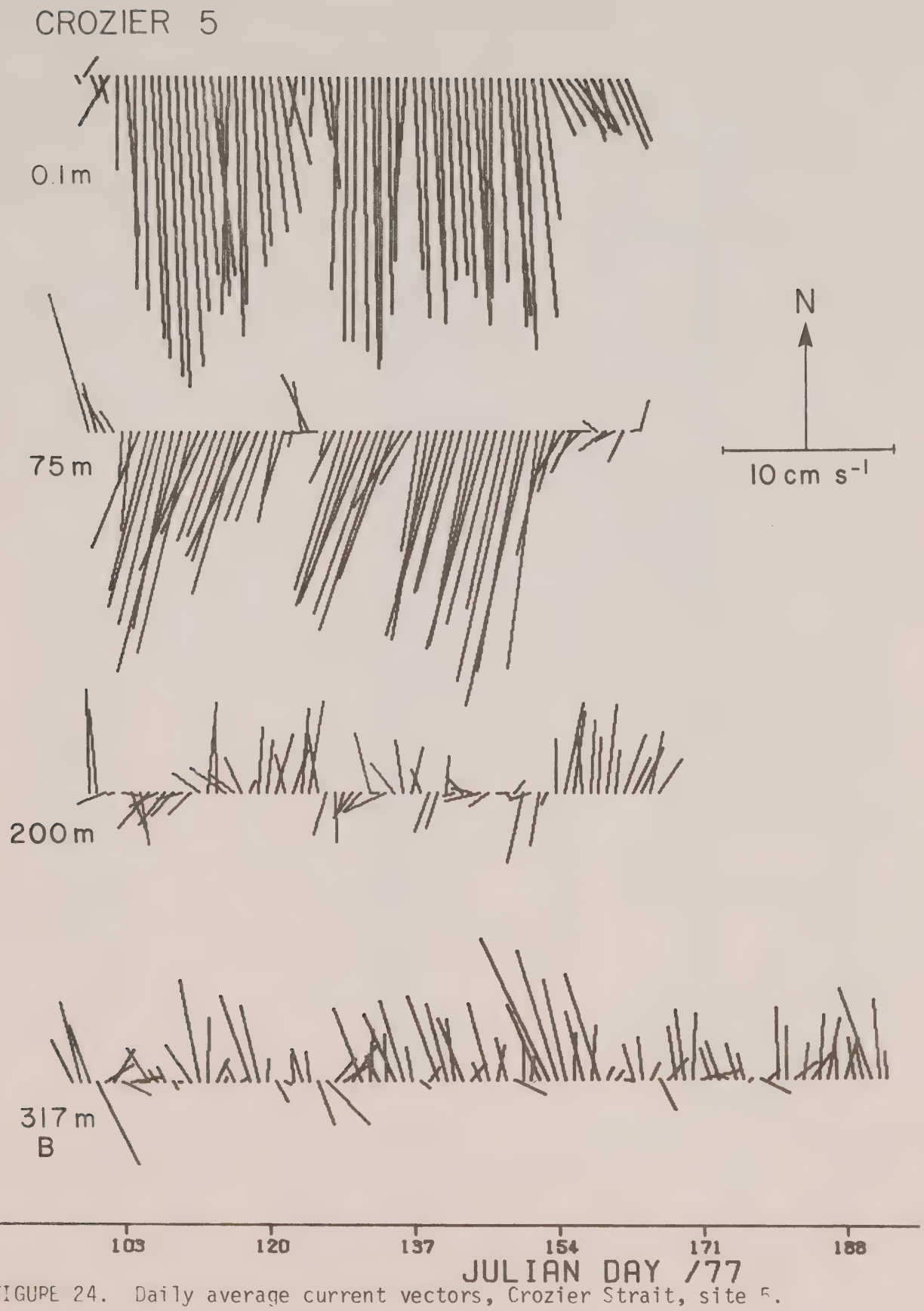


FIGURE 24. Daily average current vectors, Crozier Strait, site 5.

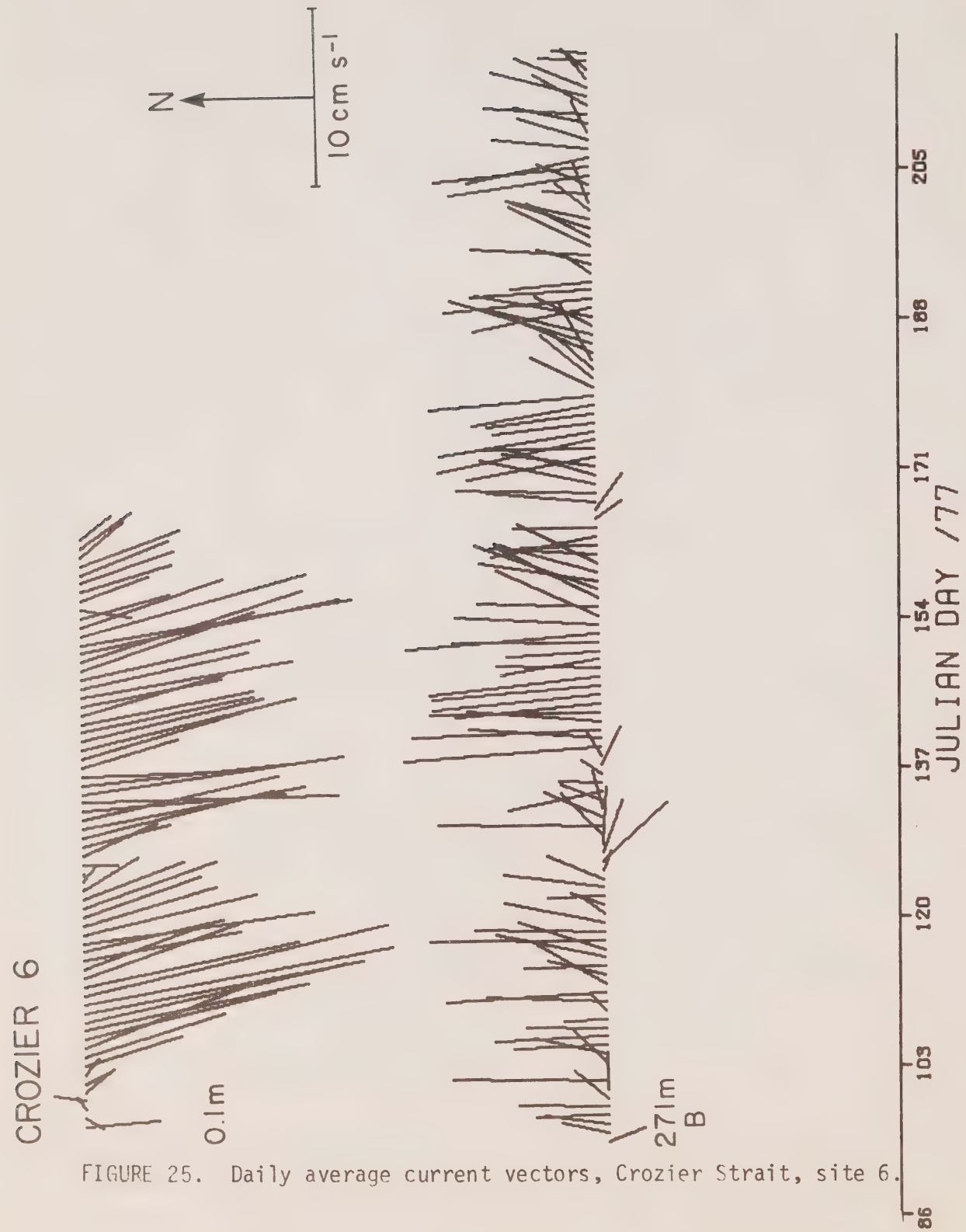


FIGURE 25. Daily average current vectors, Crozier Strait, site 6.



FIGURE 26. Daily average current vectors, Pullen Strait.

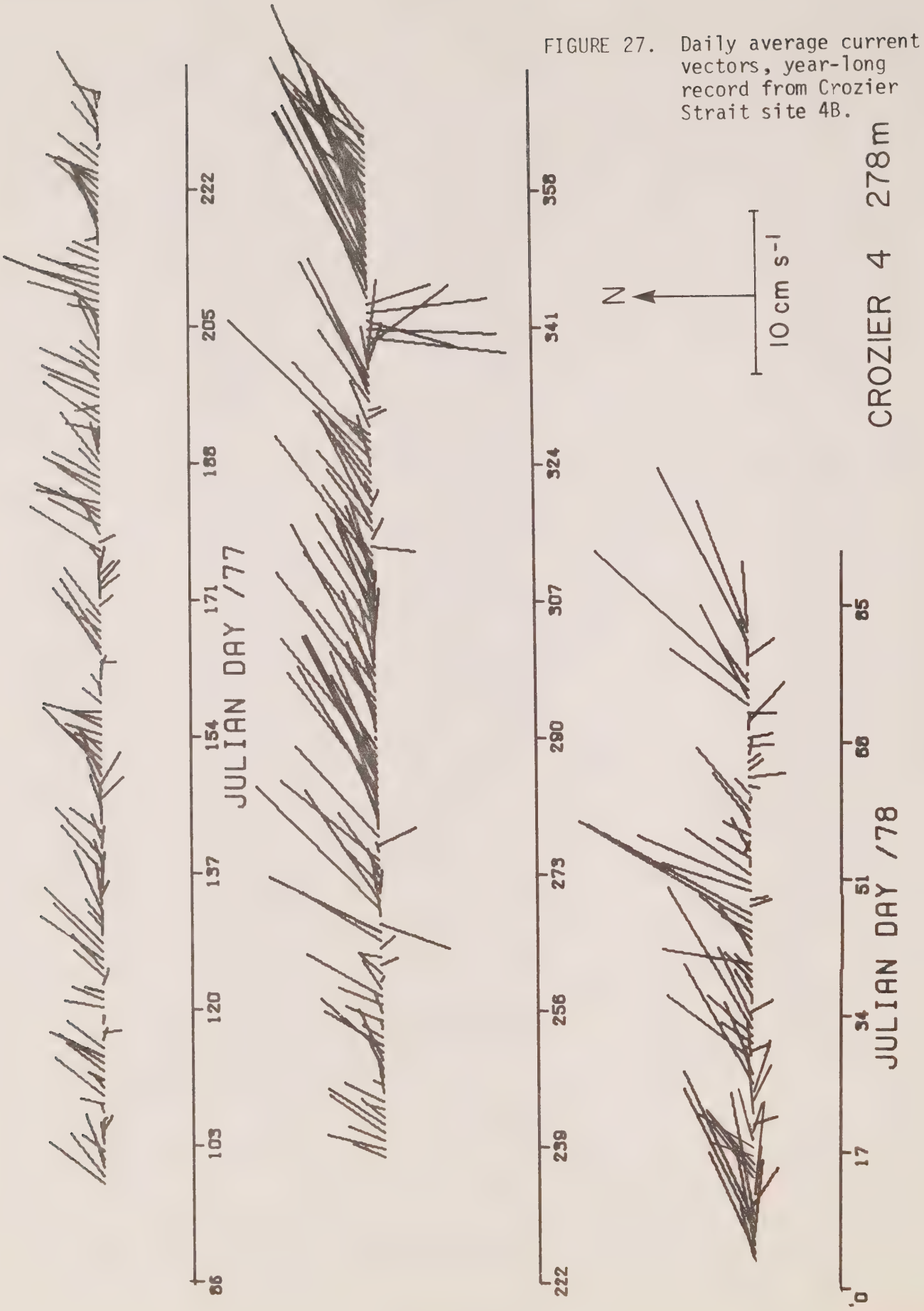


FIGURE 27. Daily average current vectors, year-long record from Crozier Strait site 4B.

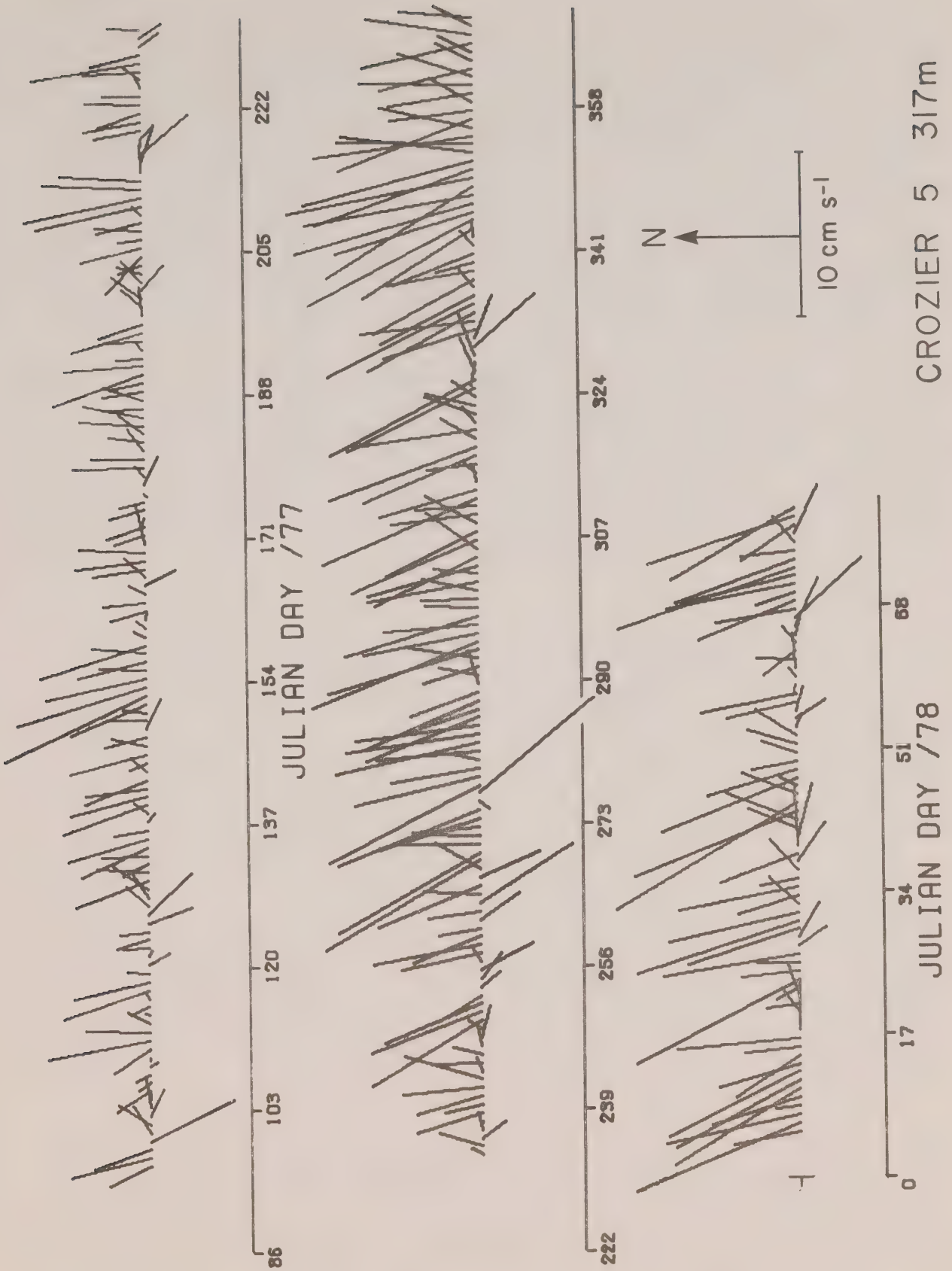


FIGURE 28. Daily average current vectors, year-long record from Crozier Strait site 5B.

However, both the mean flow and the monthly and fortnightly oscillations are much smaller (about 20%) at 200 metres than at 75 metres depth. Both the diurnal and semi-diurnal tidal oscillations at the two meters are nearly identical. The difference in the upper and lower regimes is therefore manifested in oscillations of period longer than a few days, corresponding to length scales (i.e. particle excursions) of greater than about 5 km if we take an approximate amplitude of a 10 day wave as 1 cm s^{-1}. It is no surprise that this length scale corresponds with the characteristic length scale: the width of Crozier Strait. Oscillations which have particle excursions greater than the characteristic size of the system will, of course, be strongly influenced by the local topography. It is most likely the effective sill depth of 100 metres in Queens Channel which causes the presence of the two flow regimes in Crozier Strait.

Between 75 metres and 317 metres depth the sign of the oscillations appears to change so that the daily average currents are out of phase. An increase in southward flow at 75 metres is accompanied by an increase in northward flow at 317 metres. This relationship is unclear at C4 but appears quite strongly at C6 where the surface and 271 metre current records are nearly 180° out of phase. We are unable to explain this phase change with depth in terms of internal wave theory which predicts a phase change at about 40 metres depth (see Section 4).

c) Seasonal Variations

The daily vectors from the year-long records at current meters near the bottom at C4 and C5 are shown in Figures 27 and 28. Although the general orientation of the two sets of vectors differs by about 60° the two records are quite well correlated particularly with respect to the long term variation in flow between the spring and fall. The flow is enhanced at both current meters beginning about September (Julian day 243). From these figures the flow appears to remain relatively energetic until January (particularly noticeable at C4) when the currents weaken slightly and taper almost to the values of the previous spring by March 1978.

In order to better examine this apparent seasonal variation, we computed weekly average current speeds at the two meters and plotted these versus time after applying a 3 point running mean to smooth the records. Figure 29 shows the results from the meters at sites C4 and C5. The two records display a very similar seasonal cycle with weekly averages ranging from 3 cm s^{-1} to 8 cm s^{-1}. While this range is small in absolute terms, the percent variation is striking. The peaks occur around Halloween and Christmas with a minimum between these during late November. The periods between April and September and from February through March are characterized by weekly average speeds of about 2 cm s^{-1}.

We sought to illuminate the seasonal cycle evident in the long current records by comparing it with atmospheric cycles of pressure and wind stress. We first recorded the sea level atmospheric pressure gradients over 450 km at 75°N, 95°W, in the vicinity of Resolute. For this and the other atmospheric data required we used 6 hourly charts prepared by Arctic Weather Central of Environment Canada. The gradients were obtained by the number of isobars crossed in a north-south and an east-west direction. Weekly average

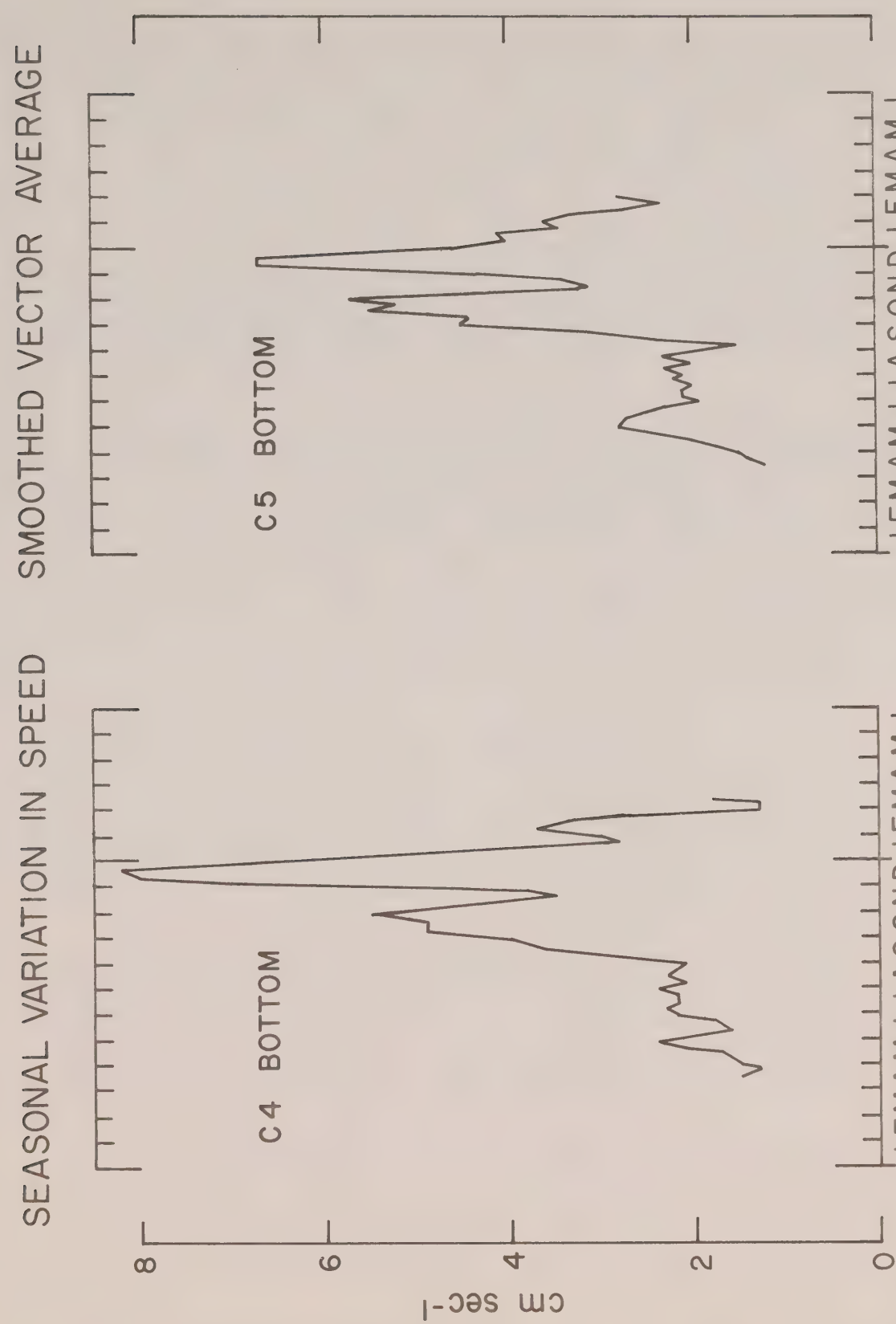


FIGURE 29. Weekly average current speeds, C4B and C5B.

pressure gradients were computed as well as the geostrophic wind components. Comparison of the flow speeds at C4B and C5B was made with the component of wind stress along Crozier Strait:

$$\underset{\sim}{\tau} \cdot \hat{e} = \left[e_x |u_g| u_g + e_y |v_g| v_g \right] \rho_a C_D \qquad 3.1$$

In 3.4 τ is the surface wind stress vector, $\hat{e}$ is the unit vector along the axis of Crozier Strait, u_g and v_g are the components of the geostrophic wind in the east and north directions, ρ_a is the density of air and C_D is the geostrophic drag coefficient. ($\rho_a C_D$ has a value of about 1.9×10^{-6} g cm^{-3}). We found no correlation between the along-channel wind stress and the long current records; not surprising since the channels are covered with land-fast ice for 9 months of the year. We next sought the sort of correlations found by Mountain, et al (1976) where the flow through Barrow Canyon was found to be driven by the atmospheric pressure gradient parallel to the Canyon axis. The atmospheric pressure gradient along the channel was computed from

$$\nabla p \cdot \hat{e} = e_x \frac{\partial p}{\partial x} + e_y \frac{\partial p}{\partial y} \qquad 3.2$$

and once again no correlation was found with the current records.

In order to refine our method of calculating pressure gradients we next compiled the pressure difference between Isachsen and Pond Inlet, i.e. two established meteorological stations. Once again no correlation was found between the atmospheric variations and those of the currents. It should be noted, however, that all the potential atmospheric driving forces calculated shared a large peak in common with the currents in December. The heightened intensity of atmospheric and oceanic motions in the winter is not, we feel, sufficient basis to conclude a causal relationship.

We are left with the impression that the variations shown in Figure 29 are caused by variations in the atmospheric circulation. We have not, however, been successful in isolating the atmospheric driving force or the appropriate scale over which it acts. It is likely that oscillations in the Central Arctic Basin are manifested as variations in flow through the archipelago, but we are unable to investigate this liklihood with existing data.

4. TIDAL FLOW

The most cursory examination of the current records from Byam and Austin Channels and Crozier and Pullen Straits reveals that they are dominated by tidal frequency oscillations. Figures 30 a,b,c,d,e and f are cross sections at 4 hour intervals in Crozier Strait East showing isotachs as measured by ten current meters over a tidal cycle. The flow regime alters drastically during the 24 hour period. Between 1400 and 1800 hrs there is an indication of a northward flowing jet which, initially on the eastern side, has its axis displaced to the western side during this 4 hour interval. There is also a consistent indication of a phase change with depth in the current oscillations since the near bottom flow is generally opposite to the flow at mid-depths and at the surface. Such a phase change suggests the presence of internal waves of tidal period.

The records were subjected to tidal stream analysis which computes the tidal ellipses for the separable constituents as well as some statistical properties of the records. The analyses show that, on the average, the tidal flows account for 75% of the variance of the records, and when the mean flow is included about 70% of the kinetic energy. Power spectra for several records were also computed and similarly showed that the variance was concentrated at the tidal frequencies. Figure 11 shows the power spectrum for current meter C5 (75 m depth) and is typical of all the records. Since most of the current measurements were made under land-fast sea ice, meteorological forcing of the ocean through direct wind stress (at least near tidal frequencies) is absent. We therefore expect a fairly "pure" tidal signal which is discussed in this section.

a) Tidal Heights

Tide gauges have been deployed in this region by various agencies. The general high quality of tide gauge data however, permits some intercomparison of these data. We consider here, very briefly, the nature of the surface tides in the region between Melville and Devon Islands.

The surface tides can be characterized by the "form number", the ratio of the two largest diurnal to the two largest semi-diurnal constituents, namely $\frac{K_1 + O_1}{M_2 + S_2}$. The ratio assumes values of 0.2 to 0.5 in this region which typify a mixed, mainly semi-diurnal tide in which there are two unequal highs and lows daily.

The propagation of the four largest constituents of the surface tide can be illustrated by examining the Greenwich phase at several stations in the region, (see Figure 31). The phases for each constituent are not entirely self consistent, so that phase differences over larger distances only should be accepted. For the K_1, M_2 and S_2 constituents, the source of the tidal energy appears to be Barrow Strait and Lancaster Sound to the east. This implies

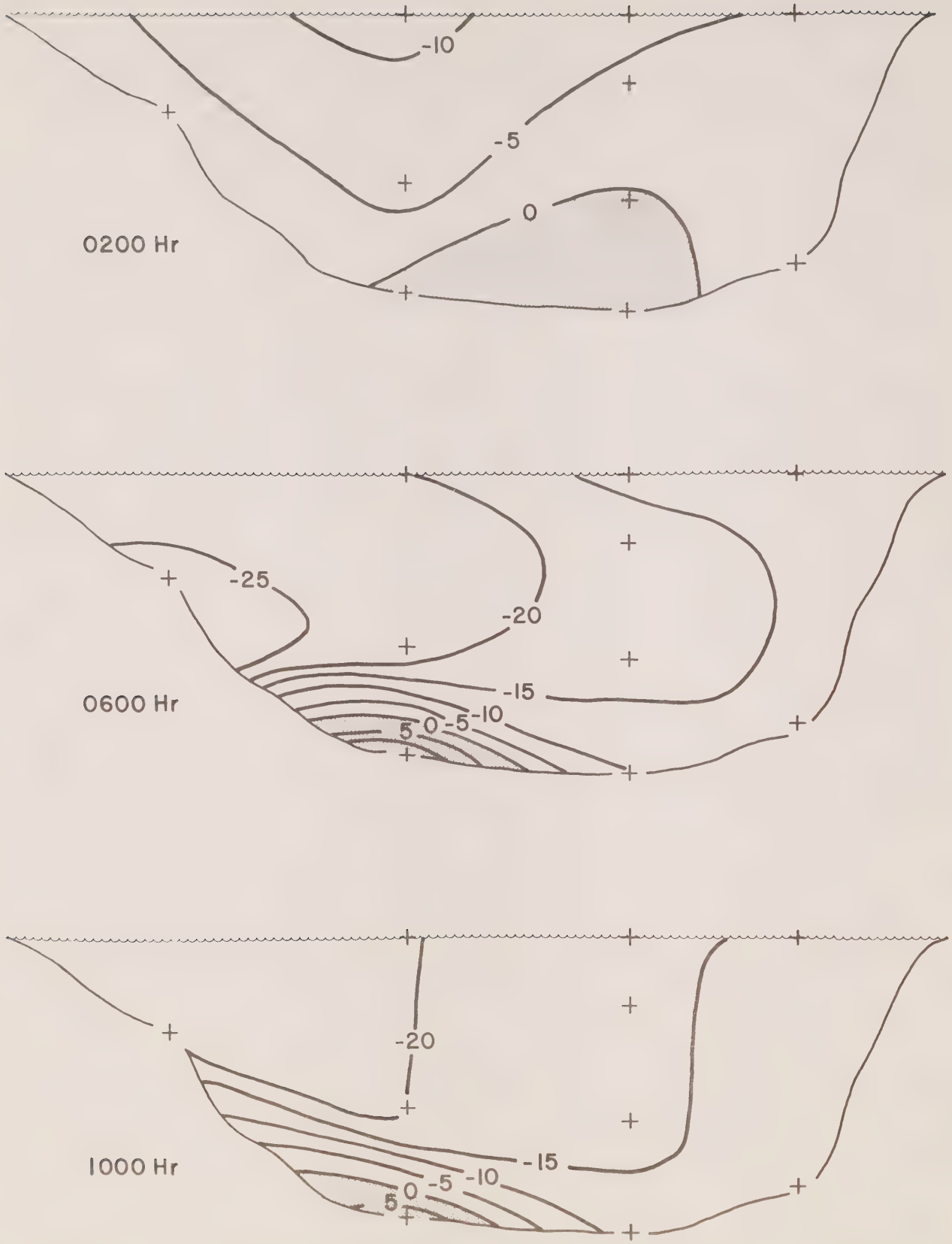


FIGURE 30. a-c Cross section of Crozier Strait east. Isotachs at 0200, 0600 and 1000 hours.

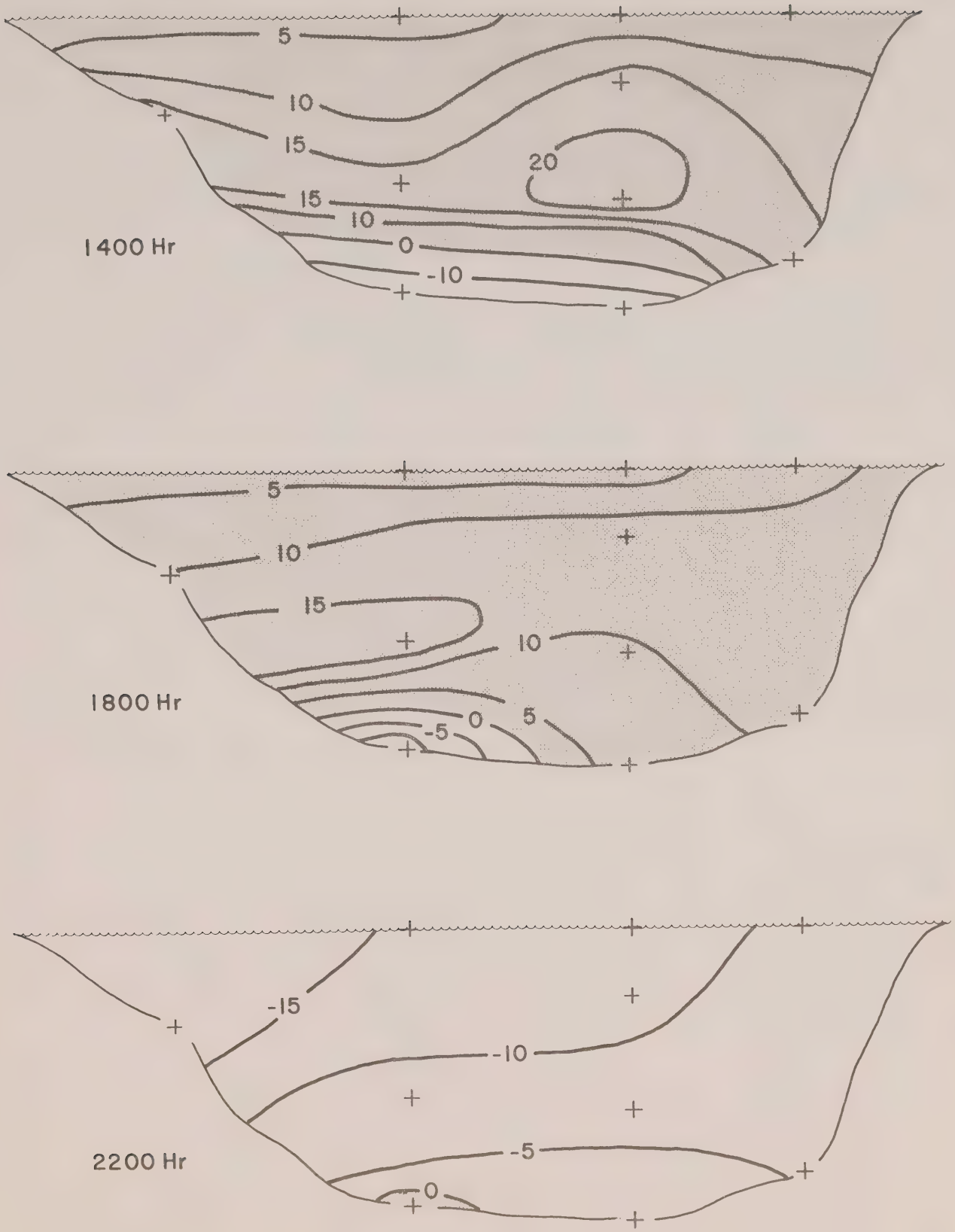


FIGURE 30. d-f Cross section of Crozier Strait east. Isotachs at 1400, 1800 and 2200 hours.



FIGURE 31. Propagation of O_1, K_1, M_2, and S_2 components in the Archipelago.

that the bulk of the tidal energy propagating into the Central Arctic is of Baffin Bay or Atlantic origin. The O_1 component cophase chart suggests that tidal energy at this frequency enters the region from both the Beaufort Sea to the west and Baffin Bay to the east.

All the tidal components display phases in the region of Cornwallis Island which imply propagation north through Wellington Channel. The O_1, M_2, and S_2 waves appear to round the northern shore of Cornwallis Island and propagate southward through Crozier and Pullen Straits. The O_1, K_1 and M_2 waves also appear to propagate northwards from Wellington Channel into Queen's Channel and through Penny Strait.

Since there is roughly a 180° phase difference in the tidal currents (Table 5) and the tidal heights (Figure 31) for the semi-diurnal components, the tide propagates as a progressive wave southward through Crozier Strait. For the diurnal components, on the other hand there is roughly a 70° phase difference between the heights and the currents which implies substantial reflection; the diurnal waves are nearly standing waves. The current data are, of course, representative of a vector time series. The data are inherently noisy relative to tidal height data and different instruments and deployment configurations frustrate attempts at intercomparison of varied experimental results. With this caution in mind, we venture to deal with the tidal currents in the remainder of this section.

b) Tidal Currents

Of the forty-one current meters deployed, seventeen were positioned with rotors about 15 cm below the ice. The bottom of the ice is not smooth and the flow is unsteady. The resulting time-dependent boundary layer seriously modifies the free stream time-dependent flow. The seventeen bottom current records too, must be influenced by the boundary.

Bergstrom and Cogley (1976) have investigated unsteady boundary layers in rotating flows of near-inertial frequency. Their results are applicable to tidal streams in wide channels where there is a significant cross-stream oscillation. Such an oscillation is manifested as a relatively large minor tidal-ellipse axis, i.e., the flow is not rectilinear but composed of clockwise and counterclockwise rotating components which combine to form an elliptical current hodograph with time as the parameter. Bergstrom and Cogley found that the deflection of the current from the free stream direction in the boundary layer is dependent upon the polarization or the sense of rotation of the free stream flow. This is contrary to the steady case where the veering in the Ekman layer is determined by the nature of momentum transfer between the ocean and the bottom (or the ice) and the rotation of the earth. They predict the major axes of the tidal ellipses in the boundary layers should lie to the left of the free stream ellipse axes in clockwise polarized flow and to the right of the free-stream ellipse axes in counterclockwise polarized flow. They also predict the decrease of ellipse size (the decrease in current speed) at various positions in the boundary layer. Their use of a constant viscosity, however, probably limits the applicability of the near boundary current speed predictions and the quantitative prediction of near-boundary

TABLE 3.

TIDAL STREAM ANALYSIS ON CURRENT RECORDS (1511 HOUR) FROM C4B.

	NAME	SPEED	MAJOR	MINOR	INC.	G
1	Z0	.00000000	.022	.000	52.6	360.0
2	MM	.00151215	.003	-.002	135.6	65.1
3	MSF	.00282193	.008	.002	107.8	25.2
4	ALP1	.03439657	.005	-.000	48.6	294.8
5	2Q1	.03570635	.003	.001	17.8	123.5
6	Q1	.03721850	.013	-.001	57.7	234.1
7	O1	.03873065	.044	-.002	77.6	331.2
8	NO1	.04026859	.004	.001	60.5	349.5
9	K1	.04178075	.063	-.005	74.2	91.2
10	J1	.04329290	.003	-.000	99.6	127.0
11	OO1	.04483084	.012	.003	56.0	355.1
12	UPS1	.04634299	.011	-.001	31.9	176.9
13	EPS2	.07617732	.006	.000	57.1	77.5
14	MU2	.07768947	.002	-.000	38.2	188.6
15	N2	.07899925	.008	-.001	65.0	12.9
16	M2	.08051140	.027	-.001	88.0	37.4
17	L2	.08202355	.004	-.001	83.0	73.9
18	S2	.08333333	.024	-.003	81.2	85.1
19	ETA2	.08507364	.006	-.001	36.1	164.7
20	MO3	.11924206	.004	-.002	48.7	16.4
21	M3	.12076710	.002	-.000	100.7	225.9
22	MK3	.12229215	.010	-.001	79.0	135.4
23	SK3	.12511408	.004	-.001	90.4	144.5
24	MN4	.15951065	.002	-.001	17.3	117.6
25	M4	.16102280	.006	-.002	58.7	169.4
26	SN4	.16233258	.002	-.000	15.9	183.1
27	MS4	.16384473	.006	-.003	67.6	181.3
28	S4	.16666667	.001	.001	42.8	154.0
29	2MK5	.20280355	.003	.001	31.8	33.9
30	2SK5	.20844741	.002	.000	87.0	23.5
31	2MN6	.24002205	.002	.000	84.5	24.4
32	M6	.24153420	.002	.000	109.8	118.6
33	2MS6	.24435613	.003	.001	70.1	65.5
34	2SM6	.24717807	.002	-.001	108.8	73.9
35	3MK7	.28331495	.002	-.001	73.8	3.3
36	M8	.32204560	.001	-.000	62.9	347.2

ellipse orientations. We can assume, however, that the sense of rotation of the tidal ellipses near the boundaries relative to the free-stream ellipses is dependent upon the polarization, either clockwise or counterclockwise, of the free-stream flow. Additionally, the superposition of the various tidal constituent ellipses and the steady flow cause instantaneous measurements of the near-boundary currents, in order to elucidate the nature of the Ekman layer, to be of little value. In fact, near-boundary current profiels were measured and demonstrated no consistent Ekman veering and a barely perceptible decrease of current speed upon approaching the ice.

All the current records were subjected to tidal stream analysis and the complete analyses are available upon request. As a sample of the relative magnitudes of the various components however, the analysis from current meter C4B is presented in Table 3. The tidal record is dominated by the O_1, K_1, M_2 and S_2 components which account for about 1/2 of the tidal energy (or 2/3 of the current amplitude), the rest being distributed among the other components, the largest of which is an order of magnitude smaller than the K_1 component.

The clockwise and counterclockwise rotating components of the current are combined in these analyses to produce tidal ellipses the rotational sense of which can be determined by the sign of the minor axis. A negative minor axis implies clockwise rotation and a positive minor axis implies counter-clockwise rotation. Godin (1972) and Foreman (1978) present a full explanation of the computational method and manipulation used in computing the tidal ellipses.

INC. is the angle in degrees between the northern semi-major axis of the tidal ellipse and the eastward direction measured counterclockwise. Its specification therefore follows standard mathematical convention for the measurement of angles. G is the Greenwich phase lag in degrees between the time the current vector lies along the northern semi-major axis and the time of maximum value of the tidal potential at Greenwich.

Tables 4 through 6 list the tidal ellipse parameters for each of the current records. The ellipse axes are drawn in the proper orientations with their centres at the appropriate locations on the channel cross sections in the Figures of Appendix B. The Greenwich phases appear near each of the ellipses. In Crozier Strait both the orientation and size of the ellipse axes are different at mid-depth locations from those at near-boundary locations, i.e. at the surface and bottom locations. As expected the tidal oscillations are somewhat damped near the upper and lower boundaries. The ellipse orientations at the surface and bottom locations are up to 30° to the left of the mid-depth locations which would be expected according to Bergstrom and Cogley if the free stream currents were polarized clockwise. The tables listing the ellipse parameters show that the free stream (mid-depth) ellipses do indeed display a clockwise rotation for 21 out of 24 current records. One of the exceptions is a case where the minor axis is computed as zero indicating a rectilinear oscillation and the other two exceptions are for the semi-diurnal constituents at site C2. The set of observations in Crozier and Pullen Straits therefore constitutes a convincing verification of the work by Bergstrom and Cogley.

The major axes of the mid-depth tidal ellipses are all directed

TABLE 4. TIDAL ELLIPSE PARAMETERS, BYAM AND AUSTIN CHANNELS

AUSTIN CHANNEL

CURRENT	M_2				S_2				K_1				O_1			
METER	MAJ	MIN	θ	G	MAJ	MIN	θ	G	MAJ	MIN	θ	G	MAJ	MIN	θ	G
A 1 T	3.5	+2.3	162	334	1.5	+1.0	128	352	5.9	-0.2	179	061	3.7	-0.3	179	341
A 2 T	3.0	+2.1	81	284	1.9	+0.3	99	343	5.6	-0.2	148	052	3.3	-0.1	146	344
A 2 B	3.6	+2.4	41	248	1.3	+0.6	159	100	7.4	+2.2	38	281	5.2	+1.8	29	204
A 3 T	2.2	+2.0	143	003	1.7	+0.4	109	011	4.7	-0.4	138	058	3.2	+0.1	136	006
A 4 T	2.9	+2.5	25	224	1.3	+0.9	92	351	4.8	+0.3	142	063	2.9	+0.4	140	348
A 5 T	5.0	+2.7	142	336	2.0	+1.0	148	027	6.8	+1.4	139	047	3.7	+1.7	127	335

BYAM CHANNEL

B 1 T	3.8	+1.1	55	008	2.1	+0.6	58	050	1.9	+0.4	76	066	1.3	+0.4	65	001
B 2 T	8.2	-1.1	78	010	2.9	+0.1	76	048	3.9	-1.5	82	067	1.8	-0.5	72	340
B 4 T	6.6	+0.8	73	021	2.7	+0.3	83	068	2.9	0.0	75	076	2.0	+0.5	69	352
B 5 T	5.9	+1.5	84	012	3.0	+1.0	91	061	3.4	+0.2	95	082	2.1	-0.1	102	359

TABLE 5. TIDAL ELLIPSE PARAMETERS, CROZIER STRAIT

CROZIER STRAIT - WEST

CURRENT	M_2				S_2				K_1				O_1			
METER	MAJ	MIN	θ	G	MAJ	MIN	θ	G	MAJ	MIN	θ	G	MAJ	MIN	θ	G
C 1 T	8.1	0.5	102	026	4.6	0.1	98	052	12.5	0.3	102	040	9.4	-0.1	106	348
C 1 M 25	11.9	-0.9	93	022	6.7	-0.2	93	050	17.6	-1.2	92	038	13.0	-0.9	92	343
C 1 B 62	8.4	1.5	122	009	6.5	0.2	124	052	8.2	-0.1	118	049	7.0	-0.7	119	338
C 2 T	9.2	2.1	110	000	5.6	0.6	107	021	10.8	-0.7	118	013	6.7	-0.6	112	322
C 2 M 25	13.5	2.5	87	004	8.0	0.4	82	021	15.4	-1.1	92	008	9.5	-0.9	96	314
C 2 B 56	8.6	3.0	97	357	5.5	0.6	98	020	11.5	-1.1	108	012	5.2	-1.3	113	304

CROZIER STRAIT - EAST

C 3 T																
C 3 B 92	7.1	-0.4	94	344	4.0	-0.7	98	022	10.3	-0.1	100	029	6.1	-0.2	94	325
C 4 T	4.8	1.0	90	006	2.2	0.8	92	044	8.1	-0.3	93	054	5.0	0.2	97	358
C 4 M 200	8.1	-0.7	83	012	4.3	-0.1	80	039	11.9	-0.4	78	042	7.3	-0.8	80	353
C 4 B 278	2.9	-0.4	85	013	2.7	0.0	81	042	6.5	-1.3	73	067	4.7	-0.7	73	355
C 5 T	4.0	1.0	102	014	2.1	0.3	105	053	7.0	0.2	96	053	4.7	0.5	94	003
C 5 M 75	7.4	-0.1	77	007	4.0	0.0	76	040	10.4	-0.8	83	049	6.8	-0.4	82	354
C 5 M 200	8.4	-0.4	86	010	4.4	-0.3	86	049	9.7	-0.9	84	052	6.2	-0.8	89	357
C 5 B 317	4.6	1.2	128	021	2.8	0.7	122	053	7.6	-0.1	124	073	5.5	-0.3	123	002
C 6 T	5.3	0.5	110	017	2.3	0.3	125	062	8.8	0.0	107	053	6.4	0.3	102	359
C 6 B 271	5.2	1.2	109	018	3.0	0.6	108	052	8.3	0.3	106	058	4.9	-0.2	101	359

TABLE 6. TIDAL ELLIPSE PARAMETERS, PULLEN STRAIT

CURRENT METER	M_2 MAJ	MIN	θ	G	S_2 MAJ	MIN	θ	G	K_1 MAJ	MIN	θ	G	O_1 MAJ	MIN	θ	G
P 3 T	10.3	-1.1	46	050	4.7	-0.5	39	074	10.0	-1.5	42	058	5.9	-0.2	39	344
P 3 M 25	15.9	-2.1	42	020	7.4	-0.9	38	048	15.4	-2.9	36	041	8.8	-0.7	35	329
P 3 B 54	11.8	1.5	62	017	5.2	1.0	53	051	11.9	-0.4	52	043	6.8	0.6	53	323

along the axes of the channels. It is of interest to note that this is also true in Pullen Strait where mean flow through the channel is nearly absent. The tidal oscillations are primarily up and down the channels since the minor axes of the tidal ellipses are generally much smaller than the major axes. The semi-diurnal ellipses from Austin Channel, on the other hand, are nearly circularly polarized, particularly for the M_2 component. The major and minor axes are barely distinguishable. Since this is the case for all the records from Austin Channel we have no reason to doubt this local phenomenon. The M_2 ellipses from Austin Channel also demonstrate the difficulty of computing the Greenwich phase when the major and minor axes of the tidal ellipses are poorly differentiated.

We have searched extensively for an explanation for the apparent absence of frictional effects on the mean flow while the tidal flow is strongly and consistently influenced by boundary friction. The explanation still eludes us. We can demonstrate the difference by examining the kinetic energies of the mean flow and the tidal oscillations at locations 15 cm from the boundary (surface) 2 metres from the boundary (bottom) and in the free stream at distances of 25 to 150 metres from the closest boundary. The partition of kinetic energy among the mean flow, the tidal oscillations and the residual is shown in Table 7. In the free-stream flow 81% of the kinetic energy is contained within the tidal oscillations which are 13.5 times as energetic as the mean flow. Near the boundaries, however, the proportion of the kinetic energy in the tidal oscillation decreases drastically. It therefore appears that the boundaries have a much stronger effect on the tidal oscillations than on the mean flow. These data imply that the effective boundary layer thickness for the tidal flow is greater than that for the mean flow.

The tidal streams can be characterized by a form number in much the same way as the tidal heights. The form numbers are computed with the sizes of the major ellipse axes for the four major tidal constituents. The average of the tidal stream form numbers in Byam and Austin Channels and Crozier and Pullen Straits is 1.4 which is characteristic of a mixed mainly semi-diurnal tide. The form number for the tidal streams is between 3 and 7 times larger than that computed for the tidal heights. The tidal currents, therefore, have a significantly stronger diurnal component than the tidal heights. Figure 31 on page 50 shows a large phase difference for the diurnal components (~30°) between Wellington Channel and Penny Strait. For the semi-diurnal components, the phase difference is roughly 10°. The larger phase difference in the diurnal oscillations will provide a larger sea surface slope and could force stronger diurnal oscillations.

The absence of a strong M_2 signal in current records in locations where it dominates tidal height records has been noted at other locations north of 75°, e.g. the West Spitsbergen Current (Greisman, 1976). The possibility therefore remains that this is not a localized phenomenon. Explanation in terms of the critical latitude for internal waves however, appears to be inapplicable in this region due to the relatively small internal tides discussed below.

The current data in Byam and Austin Channels do not permit resolution of internal oscillations. The data set from Crozier and Pullen Straits, however, contains measurements made at several mid-depth locations as well as CTD casts

TABLE 7

% KINETIC ENERGY OF THE TIDAL AND MEAN FLOWS

CROZIER STRAIT

	MEAN	TIDAL	RESIDUAL	$\frac{\text{TIDAL}}{\text{MEAN}}$
SURFACE	29	55	16	1.90
MID-DEPTH	6	81	13	13.5
BOTTOM	11	64	25	5.82

performed hourly over the tidal cycle. Knowledge of the tidal oscillations at several levels as well as the tidal mean density structure is, therefore available so that the modal structure for the internal waves can be determined. It must be borne in mind in what follows however, that most of the current measurements were made within the frictional boundary layer. The influence of friction on the near-boundary tidal oscillations is certain to affect the results of the internal tide-modal decomposition.

Internal Waves

The mode structures are the vertical standing waves between the surface and the bottom which modulate the amplitude of the oscillations of vertical excursion and vertical and horizontal particle velocities associated with the wave motion. The equation whose eigenfunctions are the internal modes is:

$$\frac{d^2w}{dz^2} + \frac{N^2(Z) - \omega^2}{\omega^2 - f^2} K_h^2 \quad w = o \qquad 4.1$$

where w is the vertical particle velocity of the wave

$N(z)$ is the Vaisala frequency, which varies with depth
ω is the wave frequency
f is the Coriolis parameter
K_h is the horizontal wave number

For a constant Vaisala frequency, $\frac{N^2(Z) - \omega^2}{\omega^2 - f^2}$ is a constant and the eigenfunctions for the vertical velocity are sines and cosines. The boundary conditions of w = 0 at z = 0, -H eliminate the cosines so that

$$w = A_1 \sin \frac{n \pi}{H} z \qquad 4.2$$

where n is the internal mode number. The mode structure of the vertical excursions is identical to that of the vertical particle velocities while the mode structure for the horizontal velocities is the z derivative of the vertical velocity modes, i.e.

$$u \propto \frac{dw}{dz} \qquad 4.3$$

where u is the horizontal particle velocity. The mode structures of the horizontal currents are, therefore cosines in z

$$u = A_Z \frac{n\pi}{H} \cos \frac{n\pi}{H} z \qquad 4.4$$

The vertical excursions and particle velocities of long internal waves in a constant N fluid are zero at the boundaries and maximum at mid-depth while the horizontal particle velocities are maximum at the surface and bottom and zero at mid-depth. The constant N condition is rarely met, however, so 4.2 must be solved for N=N(z).

The tidally averaged density profile in Crozier Strait was computed and equation 4.2 numerically solved using a program developed by Fryer for Coastal Zone Oceanography, Institute of Ocean Sciences, Patricia

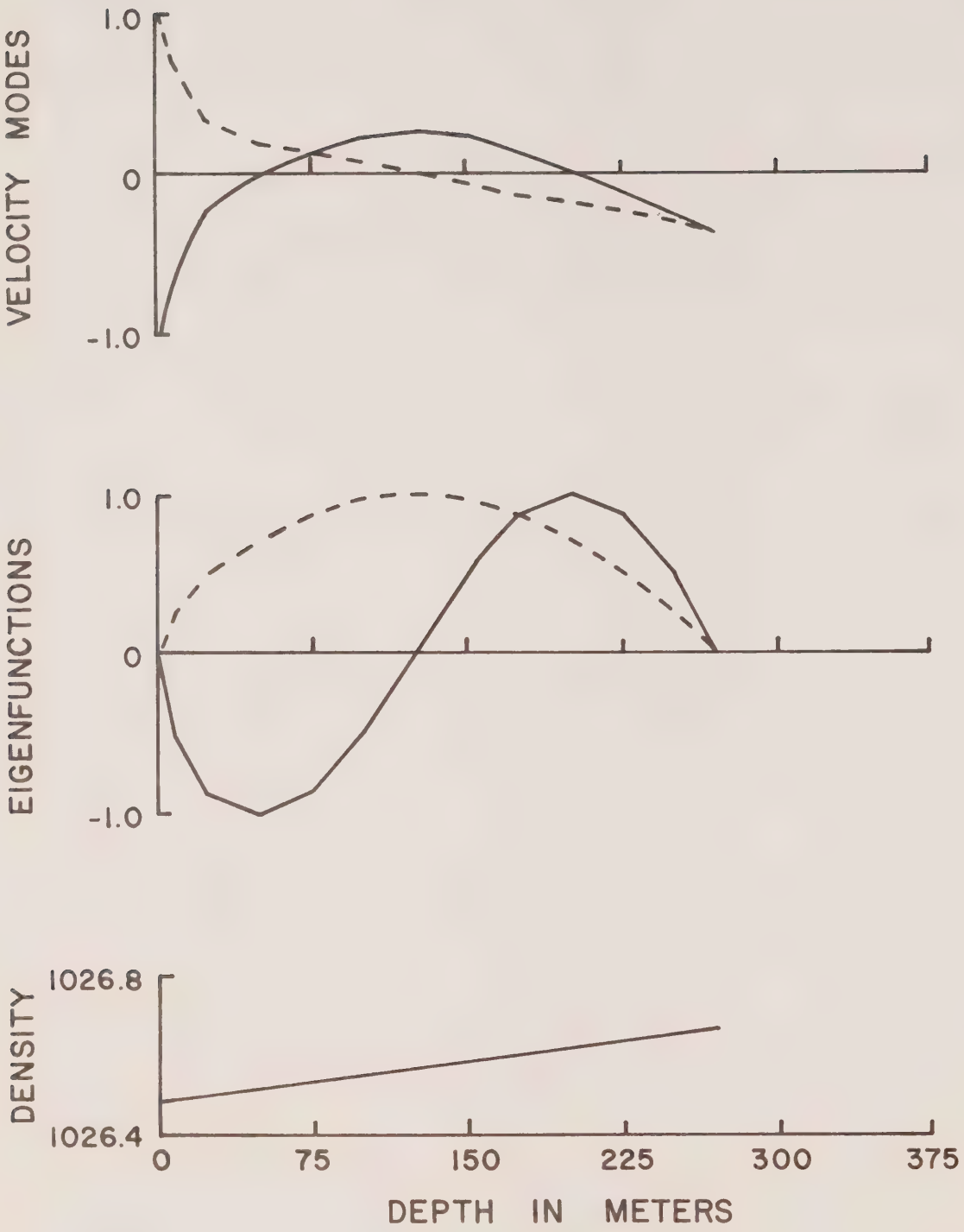


FIGURE 32. a Mode structures, constant $\frac{\partial \rho}{\partial z}$ Eigenfunctions are the structures of the vertical excursions of the waves, the velocity modes are the structures of the horizontal velocity. Broken curve is first mode; solid curve, second mode.

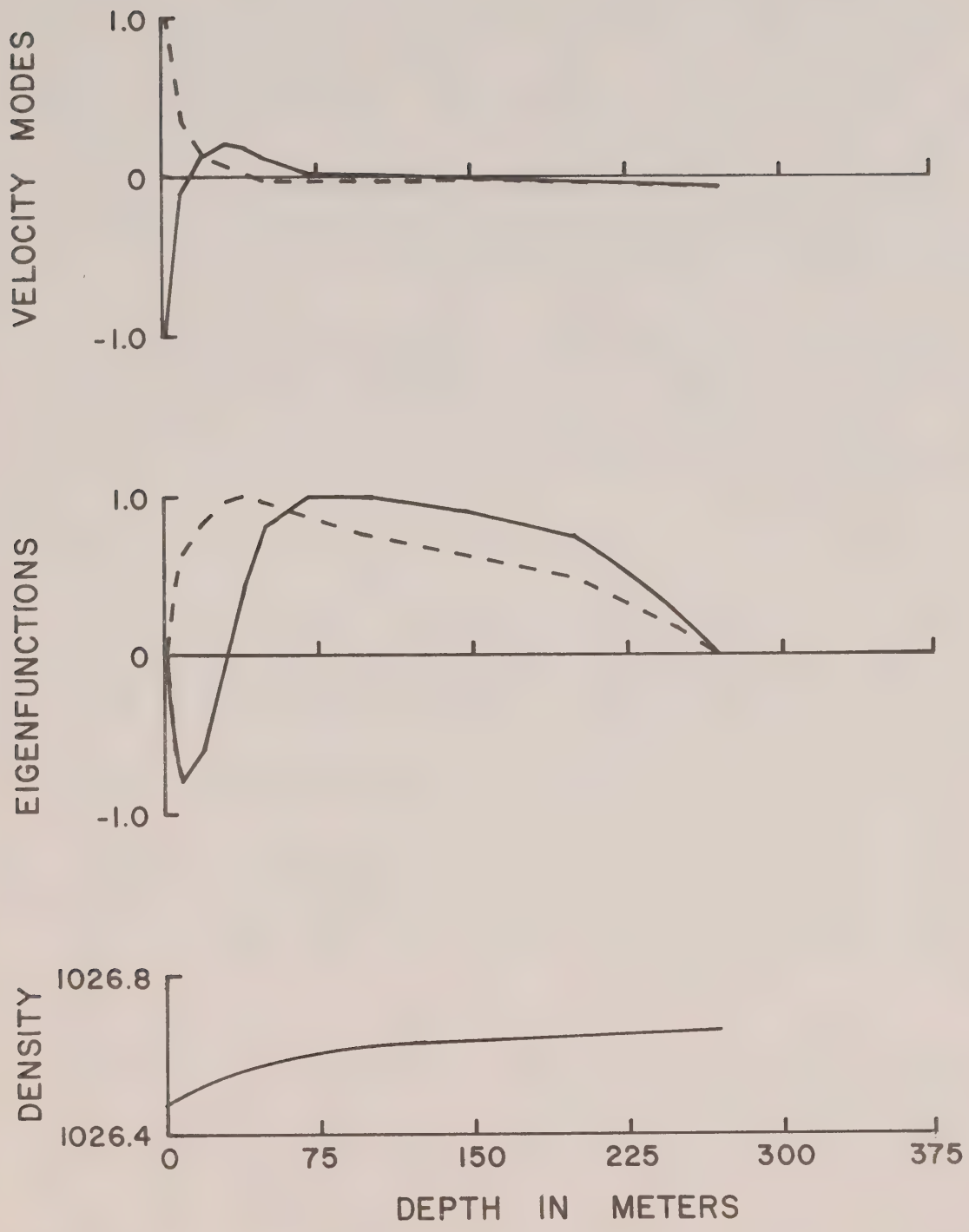


FIGURE 32. b Same as 32a except realistic ∂p/∂z.

Bay. We compared the modal structures computed by this method for the approximation of a constant density gradient (nearly a constant Vaisala frequency) and the actual stratification which is stronger near the surface. The total density difference between the surface and the bottom was held constant. The results of the computation for the first two internal modes are shown in Figure 32 a and b. The mode structure is clearly strongly affected by a relatively small change in the shape of the density profile. It should be borne in mind that relatively large variations in the Vaisala frequency are present over a tidal cycle at a given depth ($\sim 0.5 \times 10^{-3}$ s^{-1}) while the total difference in Vaisala frequency between surface and bottom is only $\sim 1.5 \times 10^{-3}$ s^{-1} . In the following modal decomposition we use a modal structure which was computed according to the method of Roberts (1975) utilising a smooth exponential fit to the Vaisala frequency profile Figures 33, a and b.

The observations of the tidal currents at each frequency must now be decomposed into a barotropic and one or more baroclinic modes. Since the eigenfunctions are orthogonal a linear combination of them will fit the observations exactly. In particular, with current data from 4 levels it is possible to precisely reproduce the observations with a barotropic and the first three baroclinic modes, by solving a set of simultaneous equations at each site for each frequency:

$$X_{jk} = U_{ji} A_{ik} \qquad 4.5$$

where X_{jk} is the size of the semi-major axis of the tidal ellipse of the k th constituent at depth j

U_{ji} is the amplitude factor from the modal structure for the i th internal mode at depth j

A_{ik} is the amplitude of the i th internal mode for the k th tidal constituent

This method, in providing an exact fit, furnishes no statistical confidence which is particularly unfortunate with these data most of which were recorded within a boundary layer. In fact such large values for the amplitudes of the internal modes were computed that severe doubts were cast on the suitability of the method.

An altogether more satisfactory procedure for modal decomposition is due to Freeland (personal communication). By computing one fewer mode amplitude than possible with the number of current meters at one location he introduces a redundancy which provides for the best least square fit of n-2 internal modes to an array of n current observations. The method multiplies the data from each meter with a weight computed from the modal structure. The weighted data sets can then be Fourier transformed and combined to yield the amplitude of the modes. We have modified Freeland's method slightly by first performing the tidal stream analysis on each data set and then weighting the amplitudes and phases of the tidal ellipse major axes.

In more detail, a matrix of the mode structure is constructed, e.g.

$$U_{ji} = \begin{pmatrix} 1 & 1 & 1 \\ & & \\ 2 & -0.6 & -0.7 \end{pmatrix}$$

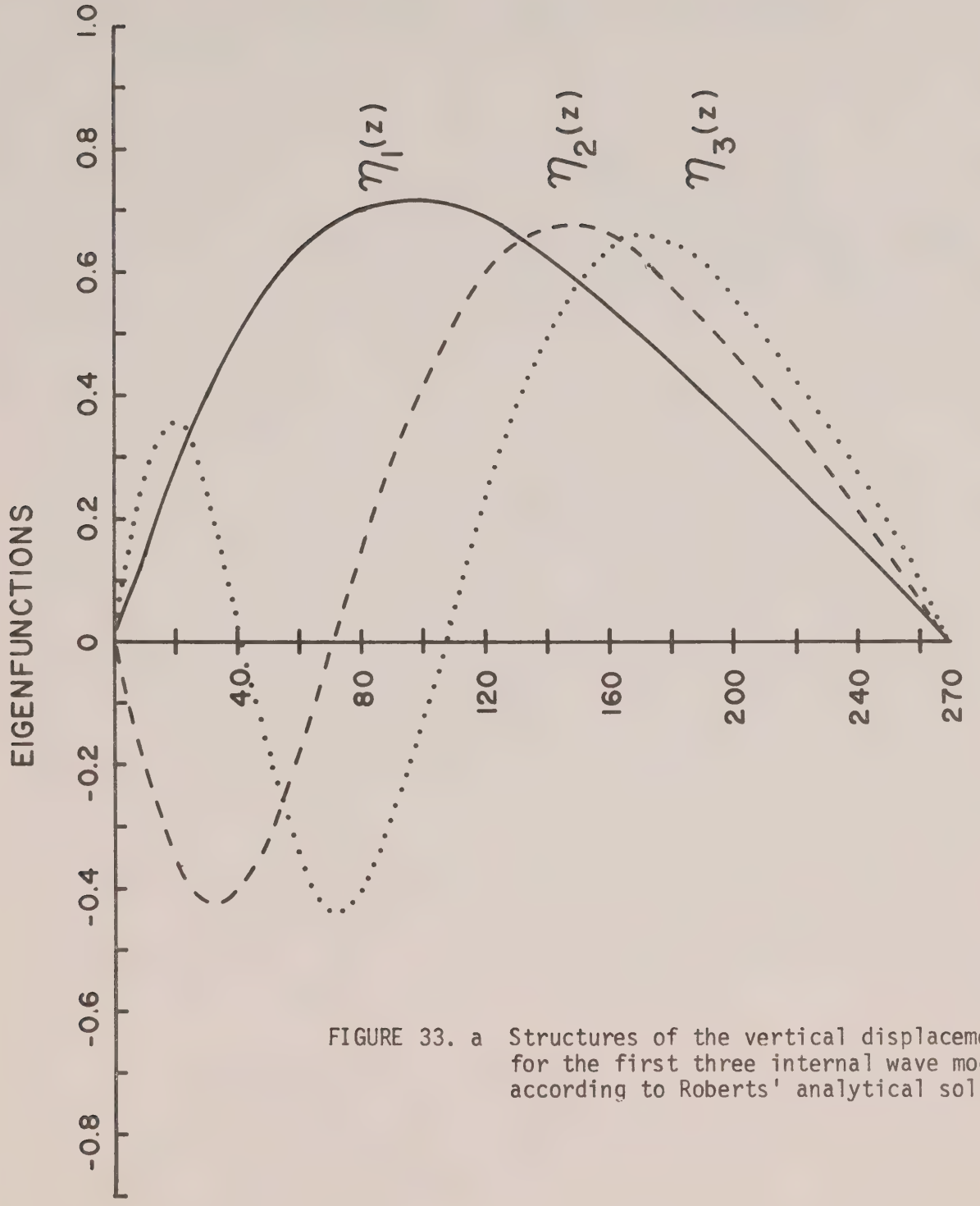


FIGURE 33. a Structures of the vertical displacements for the first three internal wave modes according to Roberts' analytical solution.

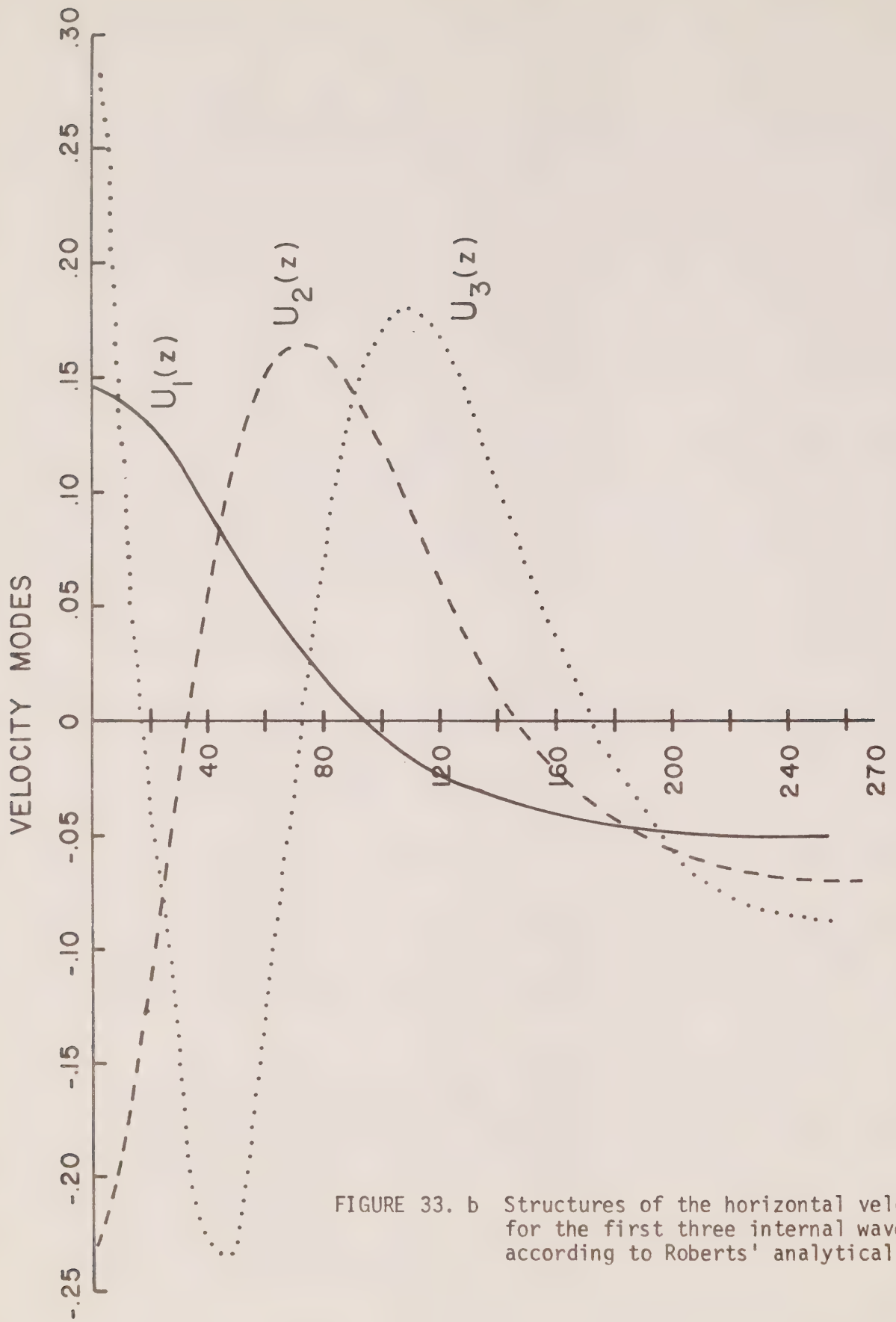


FIGURE 33. b Structures of the horizontal velocities for the first three internal wave modes according to Roberts' analytical solution.

Here the first row represents the structure of the zero th or barotropic mode which is constant with depth and the second row represents the relative current magnitudes at the depths of observation of three current meters for the first internal mode.

The matrix equation

$$X = UA \qquad 4.5'$$

must be solved as in the first method, but now U is a non-square matrix of mode structures. In order to solve for A, the modal amplitudes, an inverse of U must be computed. Freeland demonstrates that the Moore-Penrose inverse will provide the best fit of modal amplitudes to the data in the least squares sense, and,

$$U^{-1} = U^T \left[U U^T \right]^{-1} \qquad 4.6$$

$$A = U^{-1} X \qquad 4.7$$

Each of the values in the matrix X is complex, i.e., has an amplitude and phase which correspond to the size of the semi-major ellipse axis and G respectively. The modal decomposition utilizing this method produces results which are intuitively quite satisfying for a weakly stratified fluid even though the data quality for this sort of computation is severely limited by the placement of the current meters in the boundary layers. Table 8 lists the surface currents arising from the various internal modes. The amplitudes of the internal modes are generally about an order of magnitude smaller than the barotropic mode. It was possible to compute the amplitude of the second internal mode only at site C5. Here, for each of the tidal constituents, the amplitude of the second mode was found to be considerably larger than the amplitude of the first mode. This is somewhat unusual and is almost certainly due to the location of the measurements. The mid-depth meters always displayed larger tidal oscillations than the surface and bottom meters which were located in the boundary layers. The mode which best fits such an increase in tidal velocities near mid-depth is the second (see Figure 33). We therefore feel that the amplitude of the second mode has been greatly exaggerated. In fact the internal oscillation in Crozier and Pullen Straits, in particular (and probably in the nearly homogeneous tidal channels near Bathurst Island in general) appear to account for less than 5% of the tidal kinetic energy.

It should perhaps be pointed out as a post script that internal tides of some significance are sustainable in the weak stratifications of the channels near Bathurst Island. We can quickly examine the Richardson Number criterion for stability in a stratified shear flow:

$$R_i = \frac{\frac{-g}{\rho}\frac{\partial \rho}{\partial z}}{(\partial u/\partial z)^2} = \frac{N^2}{(\partial u/\partial z)^2} > 1/4 \qquad 4.8$$

TABLE 8. SURFACE CURRENTS FOR BAROTROPIC AND BAROCLINIC TIDE WAVES, CROZIER STRAIT.

(Freeland's Method)

SITE	O_1 BT	O_1 1st	O_1 2nd	K_1 BT	K_1 1st	K_1 2nd	M_2 BT	M_2 1st	M_2 2nd	S_2 BT	S_2 1st	S_2 2nd
C 1	9.75	+0.29		12.60	+0.88		9.68	-1.17		6.22	-1.55	
C 2	7.16	-0.15		12.83	-1.51		10.59	-0.91		6.47	-0.60	
C 3	6.00			10.00			7.00			4.00		
C 4	5.74	-0.71		8.91	-0.74		5.68	0.83		3.17	-0.94	
C 5	6.07	-0.14	-1.24	9.10	+0.02	-2.15	6.61	-0.71	-1.97	3.62	-0.52	-1.03
C 6	5.50			8.55			5.25			2.65		
P 3	7.36	-1.31		12.82	-2.54		13.03	-2.42		5.93	-1.06	

Using values for the Vaisala frequency from Crozier Strait and assuming the shear occurs over 50 m of water column

$$\delta u < (\delta z)\ (2)\ (N) \simeq 0.1\ m\ s^{-1}$$

About 10 cm s^{-1} over 50 m depth or 2 x 10^{-3} s^{-1} shear can be maintained before the onset of instability. We therefore have no a priori justification in minimizing the importance of internal tide-related currents in this region.

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APPENDIX A

CURRENT HISTOGRAMS

The following histograms were prepared for each, complete current meter record. The number of occurences within a speed and direction range is located in the corresponding row and column. The marginal distributions for the speed ranges summed over all direction ranges is located at the bottom of the page, while the marginal distribution for the direction ranges summed over all speed ranges is located at the right-hand side of the page.

FREQUENCY DISTRIBUTION OF DIRECTION AND RATE

BYM Ø Ø4Ø82ØØ476 GMT 1(T) 23Ø6 BYAM CHANNEL 1 75327105252 6Ø V6

CMS/SEC

DIR	2.3 TO 2.9	3 TO 5	6 TO 9	9 TO 12	12 TO 15	15 TO 18	18 TO 21	21 TO 24	24 TO 27	27 TO 3Ø	3Ø TO 33	33 TO 36	36 TO 39	39 TO 42	42 TO 45	45 TO 48	48 TO 51	51 TO 54	54 TO 57	57 TO 6Ø	6Ø TO 63	63 TO 66	66 TO 69	69 TO 72	72 TO 75	
Ø- 9	6	29	8																							43
1Ø- 19	4	2Ø	18																							42
2Ø- 29		22	27	9																						58
3Ø- 39	9	44	64	32																						149
4Ø- 49	4	55	49	13																						121
5Ø- 59	12	63	29	2																						106
6Ø- 69	6	63	1Ø																							79
7Ø- 79	7	32	6																							45
8Ø- 89	14	36	5																							55
9Ø- 99	3	14	6																							23
1ØØ-1Ø9	1	6	3																							1Ø
11Ø-119	2	13	7																							22
12Ø-129	2	16	6																							24
13Ø-139	1	13	13																							27
14Ø-149	2	19	21	1																						43
15Ø-159	1	15	19	2																						37
16Ø-169		5	8																							13
17Ø-179		11	18	2																						31
18Ø-189	3	16	15	5																						39
19Ø-199	4	15	7	2																						28
2ØØ-2Ø9	2	18	16	5																						41
21Ø-219	12	35	67	7	2																					123
22Ø-229	31	116	114	52	13																					326
23Ø-239	26	86	49	1Ø																						171
24Ø-249	4	19	1Ø	2																						35
25Ø-259	2	22	13																							37
26Ø-269	3	24	9	1																						37
27Ø-279	9	19	11																							39
28Ø-289	7	32	12																							51
29Ø-299	4	16	9																							29
3ØØ-3Ø9	6	2Ø	5	1																						32
31Ø-319	17	57	4																							78
32Ø-329	7	58	11																							76
33Ø-339	4	28	5																							37
34Ø-349		9	1																							1Ø
35Ø-359	2	12	8																							22
	1Ø78		146		Ø		Ø		Ø		Ø		Ø		Ø		Ø		Ø		Ø		Ø		Ø	2139
	217	683		15		Ø		Ø		Ø		Ø		Ø		Ø		Ø		Ø		Ø		Ø		

NUMBER OF RECORDS AT OR BELOW STALL SPEED (2.2 CM/SEC) 167

FREQUENCY DISTRIBUTION OF DIRECTION AND RATE

BYM Ø 16Ø722Ø476 GMT 2(T) 1998 BVAM CHANNEL 2 753Ø21Ø5Ø87 6Ø V6

DIR	2.3 TO 2.9	3 TO 6	6 TO 9	9 TO 12	12 TO 15	15 TO 18	18 TO 21	21 TO 24	24 TO 27	27 TO 3Ø	3Ø TO 33	33 TO 36	36 TO 39	39 TO 42	42 TO 45	45 TO 48	48 TO 51	51 TO 54	54 TO 57	57 TO 6Ø	6Ø TO 63	63 TO 66	66 TO 69	69 TO 72	72 TO 75	
CMS/SEC																										
Ø- 9	9	2Ø	34	2Ø	4		1					1														89
1Ø- 19	1	1Ø	22	6	3		2	1																		45
2Ø- 29	7	17	39	18	9																					9Ø
3Ø- 39	1	16	39	18	11																					85
4Ø- 49	1	2Ø	2Ø	14	5		1		1																	62
5Ø- 59		12	17	9	1		1																			4Ø
6Ø- 69		11	12	1																						24
7Ø- 79		2																								2
8Ø- 89	1	5	5	3	1		1																			16
9Ø- 99		5	6	1			1																			13
1ØØ-1Ø9		7	2	1																						1Ø
11Ø-119	2	4	2	1																						9
12Ø-129	1	7	5	1																						14
13Ø-139	2	13	6	1	1																					23
14Ø-149	4	18	12	3	1		2																			4Ø
15Ø-159	1	14	18	2	1																					36
16Ø-169	1	7	13	3		2	1																			27
17Ø-179	4	36	39	27	6	3	2	2	2							1										122
18Ø-189	9	43	62	54	29	11	6	7	2	3	3	2	1				1			1						234
19Ø-199	3	18	4Ø	46	17	6	4	3	3			4														144
2ØØ-2Ø9	4	36	97	65	18	1Ø	9	4	5	1		1		1							1					252
21Ø-219	1	22	35	22	8		1		1																	9Ø
22Ø-229	2	12	2Ø	7	3	3	1	1		1															1	51
23Ø-239	1	11	8	5		1																				26
24Ø-249		8	4	2	2					1																17
25Ø-259	1	5	4	2		1																				13
26Ø-269		8	5	1																						14
27Ø-279		9	5		1	1			1																	17
28Ø-289	1	4	1				1																			7
29Ø-299		12	2	1	1		2																			18
3ØØ-3Ø9	3	13	6																							22
31Ø-319	2	15	7	2	1	1																				28
32Ø-329	4	16	5	11	1	1	2	1																		41
33Ø-339	1	24	2Ø	11	3	1	1	1																		62
34Ø-349	3	21	1Ø	7	2	1		1		1																46
35Ø-359	7	37	32	12	11		1																			1ØØ
		538		377		42		21		7		8		1		1		Ø		1		1		Ø		1930
	77		655		14Ø		4Ø		15		3		1		Ø		1		Ø		Ø		Ø		1	

NUMBER OF RECORDS AT OR BELOW STALL SPEED (2.2 CM/SEC) 68

FREQUENCY DISTRIBUTION OF DIRECTION AND RATE

BYM 85 1223100576 GMT 2(B) 1396 BYAM CHANNEL 2 7530210508760 395TC V6

CMS/SEC

DIR	2.3 TO 2.9	3 TO 6	6 TO 9	9 TO 12	12 TO 15	15 TO 18	18 TO 21	21 TO 24	24 TO 27	27 TO 30	30 TO 33	33 TO 36	36 TO 39	39 TO 42	42 TO 45	45 TO 48	48 TO 51	51 TO 54	54 TO 57	57 TO 60	60 TO 63	63 TO 66	66 TO 69	69 TO 72	72 TO 75	
0- 9		3	1	1		3	2		2																	12
10- 19	2	8	5	2			1	2																		20
20- 29	2	8	4	2	1	1		3																		21
30- 39	2	26	5	1	1				1																	36
40- 49	4	19	16	1		1																				41
50- 59	4	36	30	10																						80
60- 69	4	23	20	8	1																					56
70- 79	5	36	46	12																						99
80- 89	1	32	59	20	1																					113
90- 99		15	15	4																						34
100-109	1	27	32	10																						70
110-119	1	14	9	1																						25
120-129	3	14	5																							22
130-139	1	4	5																							10
140-149	1	7	2	1																						11
150-159	2	6	2																							10
160-169		5	1																							6
170-179	1	5	3	2		1																				12
180-189	2	4	2	1																						9
190-199		3	5																							8
200-209		4	1																							5
210-219	1	9	6	2																						18
220-229		9	14	5	1		1																			30
230-239	1	9	22	4	3																					39
240-249	4	23	22	10	2																					61
250-259	3	26	27	10	1																					67
260-269	3	22	20	11	1																					57
270-279	2	18	13	6	1																					40
280-289	3	15	22	9																						49
290-299	1	8	4	3	1																					17
300-309	1	7	10	3																						21
310-319	1	6	7	2																						16
320-329		7	3	3																						13
330-339		6	3	1				1																		11
340-349	1	4	8						1																	13
350-359	1	5	2																							9
		473		145		6		6		Ø		Ø		Ø		Ø		Ø		Ø		Ø		Ø		1161
	58		451		14		4		4		Ø		Ø		Ø		Ø		Ø		Ø		Ø		Ø	

NUMBER OF RECORDS AT OR BELOW STALL SPEED (2.2 CM/SEC) 51

FREQUENCY DISTRIBUTION OF DIRECTION AND RATE

BYM 62 2422100576 GMT 3(B) 1274 BYAM CHANNEL 3 75269104574 60 216TC V6

CMS/SEC

DIR	2.3 TO 2.9	3 TO 6	6 TO 9	9 TO 12	12 TO 15	15 TO 18	18 TO 21	21 TO 24	24 TO 27	27 TO 30	30 TO 33	33 TO 36	36 TO 39	39 TO 42	42 TO 45	45 TO 48	48 TO 51	51 TO 54	54 TO 57	57 TO 60	60 TO 63	63 TO 66	66 TO 69	69 TO 72	72 TO 75	
0- 9	1	3	9	17	4	3																				37
10- 19		3	13	13	7	1	1																			38
20- 29		4	11	6	4																					25
30- 39		1	3	2																						6
40- 49		4	5	4																						13
50- 59		4	10	2																						16
60- 69		4	10	4																						18
70- 79		7	12	3																						22
80- 89		1	3	1																						5
90- 99	1	1	3	1																						6
100-109		3	2	3																						8
110-119		4	4	5																						13
120-129		3	9	8	4																					24
130-139	1	4	11	33	5																					54
140-149		2	10	27	9	2																				50
150-159	1	5	14	20	6		2																			48
160-169	1	6	18	21	6																					52
170-179		5	14	18	12		1																			50
180-189	1	5	13	22	14	1		1																		57
190-199		4	12	11	10		1																			38
200-209			2	5	8	1																				16
210-219		2	3	4	4																					13
220-229		3	2	2	2	1	1																			11
230-239		1		1	1																					3
240-249	1	5	1	4																						11
250-259		3	4																							7
260-269	1	3	1																							5
270-279		1	2																							3
280-289			1	1																						2
290-299		3	4	3																						10
300-309		2	3						1																	6
310-319		3	3			1																				7
320-329		1	1	2																						4
330-339		2	13	1																						16
340-349	1	3	8	3	1																					16
350-359			5	9	1																					15
	105		256		10		1		0		0		0		0		0		0		0		0			727
	9	240		99		6		1		0		0		0		0		0		0		0		0		

NUMBER OF RECORDS AT OR BELOW STALL SPEED (2.2 CM/SEC) 1

FREQUENCY DISTRIBUTION OF DIRECTION AND RATE

BYM Ø 4Ø212Ø476 GMT 4(T) 1464 BYAM CHANNEL 4 75269Ø4574 6Ø V6

DIR	2.3 TO 2.9	3 TO 6	6 TO 9	9 TO 12	12 TO 15	15 TO 18	18 TO 21	21 TO 24	24 TO 27	27 TO 3Ø	3Ø TO 33	33 TO 36	36 TO 39	39 TO 42	42 TO 45	45 TO 48	48 TO 51	51 TO 54	54 TO 57	57 TO 6Ø	6Ø TO 63	63 TO 66	66 TO 69	69 TO 72	72 TO 75	CMS/SEC
Ø- 9	1Ø	34	27	9																						8Ø
1Ø- 19		17	21	4																						42
2Ø- 29	8	49	61	15	4	1																				138
3Ø- 39	4	27	32	4	2																					69
4Ø- 49	3	18	9	2																						32
5Ø- 59	2	17	6	1																						26
6Ø- 69	1	11	2																							14
7Ø- 79	1	1																								2
8Ø- 89		3	1																							4
9Ø- 99	1	5	1				1																			8
1ØØ-1Ø9	1	5																								6
11Ø-119	1	3																								4
12Ø-129	1	6				1																				8
13Ø-139	3	4	2		1																					1Ø
14Ø-149	3	7	3	1																						14
15Ø-159	1	7	4	3	1																					16
16Ø-169	1	5	8	5																						19
17Ø-179	2	25	25	8	2																					62
18Ø-189	8	32	61	42	8	3	1	1	1																	157
19Ø-199	1	34	47	28	15				1																	126
2ØØ-2Ø9	11	57	95	49	13		1	1																		227
21Ø-219	5	38	37	13	8																					1Ø1
22Ø-229	2	19	17	2	1	1	1																			43
23Ø-239	5	14	1																							2Ø
24Ø-249	3	7	1																							11
25Ø-259		5																								5
26Ø-269	1	5	3																							9
27Ø-279	2	5	2	1			1																			11
28Ø-289	5	4		1																						1Ø
29Ø-299	2	1	2																							5
3ØØ-3Ø9	2	1Ø	2																							14
31Ø-319	6	1Ø	7																							23
32Ø-329	4	1Ø	2																							16
33Ø-339	4	17	5	1																						27
34Ø-349	1	9	2																							12
35Ø-359	7	25	11	1																						44
		548		19Ø		6		2		Ø		Ø		Ø		Ø		Ø		Ø		Ø		Ø		1417
	112		497		55		5		2		Ø		Ø		Ø		Ø		Ø		Ø		Ø		Ø	

NUMBER OF RECORDS AT OR BELOW STALL SPEED (2.2 CM/SEC) 47

FREQUENCY DISTRIBUTION OF DIRECTION AND RATE

BYM Ø 5220120576 GMT 5(T) 1760 BYAM CHANNEL 5 75255104378 60 V6

CMS/SEC

DIR	2.3 TO 2.9	3 TO 6	6 TO 9	9 TO 12	12 TO 15	15 TO 18	18 TO 21	21 TO 24	24 TO 27	27 TO 30	30 TO 33	33 TO 36	36 TO 39	39 TO 42	42 TO 45	45 TO 48	48 TO 51	51 TO 54	54 TO 57	57 TO 60	60 TO 63	63 TO 66	66 TO 69	69 TO 72	72 TO 75	
Ø- 9	1	20	39	25	20	7	1																			113
10- 19	2	13	23	27	5	4																				74
20- 29		20	31	19	8	4	1																			83
30- 39		31	29	11	1																					72
40- 49	1	26	12	6																						45
50- 59	1	16	11	5	1																					34
60- 69	2	20	10	7	1																					40
70- 79		11																								11
80- 89		2	5	2	1																					10
90- 99	6	18	4	1	1																					30
100-109		16	4	1																						21
110-119		10	3																							13
120-129	2	17	13	1																						33
130-139	1	23	7																							31
140-149	1	22	18	11	5																					57
150-159	3	39	33	20	4	3																				102
160-169	3	53	39	24	6	3																				128
170-179	7	34	38	23	3	2																				107
180-189	10	51	63	25	9	1	3				1															163
190-199	6	29	16	4	4	1																				60
200-209	5	26	21	6		1	1	1																		61
210-219	2	12	16	5																						35
220-229	1	13	7	2	1																					24
230-239		6	6	1																						13
240-249	1	8	4	2																						15
250-259	2	2	3		1																					8
260-269	1	2	4	2																						9
270-279	1	5	3																							9
280-289			5	1																						6
290-299		5	8	3																						16
300-309		4	6	3	1																					14
310-319		6	11	2																						19
320-329		12	13	2																						27
330-339		11	17	6	2																					36
340-349	1	5	7	8	4																					25
350-359		15	18	16	2	4	1																			56
	60	603	547	271	81	30	7	1	Ø	Ø	1	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	1601

NUMBER OF RECORDS AT OR BELOW STALL SPEED (2.2 CM/SEC) 159

FREQUENCY DISTRIBUTION OF DIRECTION AND RATE

BYM 44 4822120576 GMT 5(B) 1141 BYAM CHANNEL 5 75255104378 60 504T V6

CMS/SEC

DIR	2.3 TO 2.9	3 TO 6	6 TO 9	9 TO 12	12 TO 15	15 TO 18	18 TO 21	21 TO 24	24 TO 27	27 TO 30	30 TO 33	33 TO 36	36 TO 39	39 TO 42	42 TO 45	45 TO 48	48 TO 51	51 TO 54	54 TO 57	57 TO 60	60 TO 63	63 TO 66	66 TO 69	69 TO 72	72 TO 75	
0- 9	1	7	6	1																						15
10- 19		11	15	2																						28
20- 29		7	15	5																						27
30- 39	1	9	18	12	4	2																				46
40- 49		18	31	30	20	6																				105
50- 59		9	25	23	7	5	1																			70
60- 69		14	18	11	5	3	1																			52
70- 79		4	3																							7
80- 89	1	4	8	1																						14
90- 99		9	2																							11
100-109		1	3																							4
110-119		4	2																							6
120-129		7	3																							10
130-139		3	1																							4
140-149		7	5																							12
150-159		9	5																							14
160-169		6	11	2																						19
170-179	1	11	8	2																						22
180-189		7	13	4	1																					25
190-199	1	7	12	5																						25
200-209		3	12	3	6																					24
210-219		6	13	11	6	1																				37
220-229		5	20	16	23	2																				66
230-239	1	19	23	15	11	1																				70
240-249	1	11	13	5	6	2																				38
250-259	4	17	9	3																						33
260-269		6	6	1																						13
270-279		11	1																							12
280-289	1	7	1																							9
290-299		7	1																							8
300-309		3																								3
310-319		5	3																							8
320-329		5	1																							6
330-339		7	1																							8
340-349		8																								8
350-359	1	7	4																							12
	282		152		22		0		0		0		0		0		0		0		0		0			872
	13	312		89		2		0		0		0		0		0		0		0		0		0		

NUMBER OF RECORDS AT OR BELOW STALL SPEED (2.2 CM/SEC) 7

FREQUENCY DISTRIBUTION OF DIRECTION AND RATE

AUS Ø 1Ø171ØØ576 GMT 1(T) 1732 AUSTIN CHANNEL 1 75252103501 6Ø V6

CMS/SEC

DIR	2.3 TO 2.9	3 TO 6	6 TO 9	9 TO 12	12 TO 15	15 TO 18	18 TO 21	21 TO 24	24 TO 27	27 TO 3Ø	3Ø TO 33	33 TO 36	36 TO 39	39 TO 42	42 TO 45	45 TO 48	48 TO 51	51 TO 54	54 TO 57	57 TO 6Ø	6Ø TO 63	63 TO 66	66 TO 69	69 TO 72	72 TO 75	
Ø- 9	4	14	7																							25
1Ø- 19	1	7	1																							9
2Ø- 29	5	2Ø	1Ø	1																						36
3Ø- 39	9	29	14	7																						59
4Ø- 49	5	29	22	3	1																					6Ø
5Ø- 59	7	28	29	1																						65
6Ø- 69	1	26	17	6																						5Ø
7Ø- 79	2	16	6	1																						25
8Ø- 89	4	41	21	9																						75
9Ø- 99	4	48	62	11	2																					127
1ØØ-1Ø9	7	24	31	12	2	1																				77
11Ø-119	5	48	88	53	13	1																				2Ø8
12Ø-129	5	58	36	35	13																					147
13Ø-139	5	15	1Ø	3																						33
14Ø-149	7	17	1																							25
15Ø-159	6	25	2																							33
16Ø-169	5	2																								7
17Ø-179	6	8																								14
18Ø-189	1Ø	14																								24
19Ø-199	2	9	2																							13
2ØØ-2Ø9	2	15	6																							23
21Ø-219	2	12	9	1																						24
22Ø-229	2	19	11																							32
23Ø-239	5	18	12	1	2																					38
24Ø-249	1	15	25	6	2																					49
25Ø-259	3	12	25	11	2																					53
26Ø-269		12	26	24	6	1																				69
27Ø-279	5	23	21	21	8	1																				79
28Ø-289	2	6	7	12	1																					28
29Ø-299	6	11	2Ø	6	5																					48
3ØØ-3Ø9	4	13	3	1																						21
31Ø-319	3	1Ø	1																							14
32Ø-329		12	1																							13
33Ø-339	3	18	1																							22
34Ø-349	3	1Ø	2																							15
35Ø-359	2	17																								19
	7Ø2		225		4		Ø		Ø		Ø		Ø		Ø		Ø		Ø		Ø		Ø		Ø	166Ø
	143	529		57		Ø		Ø		Ø		Ø		Ø		Ø		Ø		Ø		Ø		Ø		

NUMBER OF RECORDS AT OR BELOW STALL SPEED (2.2 CM/SEC) 72

FREQUENCY DISTRIBUTION OF DIRECTION AND RATE

AUS1Ø8 Ø623100576 GMT 1(B) 1723 AUSTIN CHANNEL 1 752521Ø35Ø1 6Ø 771TC V6

CMS/SEC

DIR	2.3 TO 2.9	3 TO 6	6 TO 9	9 TO 12	12 TO 15	15 TO 18	18 TO 21	21 TO 24	24 TO 27	27 TO 3Ø	3Ø TO 33	33 TO 36	36 TO 39	39 TO 42	42 TO 45	45 TO 48	48 TO 51	51 TO 54	54 TO 57	57 TO 6Ø	6Ø TO 63	63 TO 66	66 TO 69	69 TO 72	72 TO 75	
Ø- 9	2	21	11	1																						35
1Ø- 19		6	7																							13
2Ø- 29	2	14	5																							21
3Ø- 39	5	2Ø	1Ø	1																						36
4Ø- 49		12																								12
5Ø- 59		1Ø	3																							13
6Ø- 69		15	3																							18
7Ø- 79		6	4	1																						11
8Ø- 89	1	13	6																							2Ø
9Ø- 99		1Ø	6																							16
1ØØ-1Ø9	1	9	18	16	3																					47
11Ø-119		12	23	21	1Ø			1																		67
12Ø-129		12	19	12	3																					46
13Ø-139		2	9	6	2	1																				2Ø
14Ø-149		5	6	4	4																					19
15Ø-159		7	5	2	1																					15
16Ø-169		2	4																							6
17Ø-179		7	2	2																						11
18Ø-189		4	1																							5
19Ø-199	1	4	4		1	1																				11
2ØØ-2Ø9	1	2	4	1		1																				9
21Ø-219		4	3	1																						8
22Ø-229		7	2																							9
23Ø-239		5	2	3		2																				12
24Ø-249		6	7			1	1																			15
25Ø-259	2		2																							4
26Ø-269		1	3	1	1	1	1																			8
27Ø-279		4	6	1	1				1																	13
28Ø-289		4	2	1	3	1		1																		12
29Ø-299	1	9	6	5	5	3	2																			31
3ØØ-3Ø9		9	5	4	6	3	2	1																		3Ø
31Ø-319		5	6	11	3	2	2	2																		31
32Ø-329		15	8	1	4																					28
33Ø-339	1	16	18	1Ø	2																					47
34Ø-349	2	24	17	9	1																					53
35Ø-359	2	35	13	6																						56
		342		121		16		5		Ø		Ø		Ø		Ø		Ø		Ø		Ø		Ø		815
	21		251		5Ø		8		1		Ø		Ø		Ø		Ø		Ø		Ø		Ø		Ø	

NUMBER OF RECORDS AT OR BELOW STALL SPEED (2.2 CM/SEC) 16

FREQUENCY DISTRIBUTION OF DIRECTION AND RATE

AUS ø 2216ø9ø576 GMT 2(T) 1298 AUSTIN CHANNEL 2 75264ø3387 6ø V6

CMS/SEC

DIR	2.3 TO 2.9	3 TO 6	6 TO 9	9 TO 12	12 TO 15	15 TO 18	18 TO 21	21 TO 24	24 TO 27	27 TO 3ø	3ø TO 33	33 TO 36	36 TO 39	39 TO 42	42 TO 45	45 TO 48	48 TO 51	51 TO 54	54 TO 57	57 TO 6ø	6ø TO 63	63 TO 66	66 TO 69	69 TO 72	72 TO 75	
ø- 9	3	8	1																							12
1ø- 19	4	7																								11
2ø- 29	3	13	1																							17
3ø- 39	3	18	2																							23
4ø- 49	2	26	5																							33
5ø- 59	4	31	4																							39
6ø- 69	6	32	8	1																						47
7ø- 79	1	15	3	1																						2ø
8ø- 89	3	27	5																							35
9ø- 99	1	3ø	11	1																						43
1ø8-1ø9		27	15			1																				43
11ø-119	3	15	14	1																						33
12ø-129		29	46	4	1	1																				81
13ø-139	1	33	61	24	3																					122
14ø-149	3	24	64	54	8																					153
15ø-159	4	18	21	18	1ø	1																				72
16ø-169	1	1ø	6	1	1																					19
17ø-179		13	1		1																					15
18ø-189	3	11	2																							16
19ø-199	1	6																								7
2ø8-2ø9		5	1																							6
21ø-219		2	3																							5
22ø-229	1	9	1	1																						12
23ø-239		9	7																							16
24ø-249	1	13	13		1																					28
25ø-259	1	12	4	1																						18
26ø-269	2	19	13		1																					35
27ø-279	1	22	9	2																						34
28ø-289	1	16	12	2																						31
29ø-299	3	16	26	2																						47
3ø8-3ø9	4	23	32																							59
31ø-319	3	21	7	2																						33
32ø-329	2	16	1ø	1																						29
33ø-339	3	7	6	1																						17
34ø-349	3	6																								9
35ø-359	5	14																								19
	76	6ø3	414	117	26	3	ø	ø	ø	ø	ø	ø	ø	ø	ø	ø	ø	ø	ø	ø	ø	ø	ø	ø	1239

NUMBER OF RECORDS AT OR BELOW STALL SPEED (2.2 CM/SEC) 51

FREQUENCY DISTRIBUTION OF DIRECTION AND RATE

AUS142 1822080576 GMT 2(B) 2518 AUSTIN CHANNEL 2 75264103387 60 454TC V6

CMS/SEC

DIR	2.3 TO 2.9	3 TO 6	6 TO 9	9 TO 12	12 TO 15	15 TO 18	18 TO 21	21 TO 24	24 TO 27	27 TO 30	30 TO 33	33 TO 36	36 TO 39	39 TO 42	42 TO 45	45 TO 48	48 TO 51	51 TO 54	54 TO 57	57 TO 60	60 TO 63	63 TO 66	66 TO 69	69 TO 72	72 TO 75	
0- 9	3	22	12	3																						40
10- 19	5	32	13	4																						54
20- 29	3	36	31	6	1																					77
30- 39	5	30	24	12	1																					72
40- 49	3	34	30	17	1																					85
50- 59	3	21	23	5	1																					53
60- 69	5	46	37	12	5																					105
70- 79	3	42	26	7	5	1																				84
80- 89	3	32	18	9	1																					63
90- 99	3	21	5	5																						34
100-109	2	11	7	1																						21
110-119	3	7	3	1																						14
120-129	4	5	5																							14
130-139		10	1	2																						13
140-149	1	4	2																							7
150-159		12	4																							16
160-169	1	15	11	2																						29
170-179		14	15	13	1																					43
180-189	1	21	8	8	2																					40
190-199	2	29	75	38	10	1																				155
200-209	3	54	70	62	32	6																				227
210-219	5	26	41	49	43	9																				173
220-229	1	26	28	32	36	10	5																			138
230-239	2	23	30	36	27	16	7																			141
240-249	2	26	23	45	24	18	6	3																		147
250-259	2	39	38	25	26	20	17	1																		168
260-269	2	17	20	5	23	17	11	3																		98
270-279	2	16	6	6	2	10	5																			47
280-289	1	28	16	2		1	3																			51
290-299	4	18	6	2																						30
300-309	1	10	7	1																						19
310-319	3	18	9	4																						34
320-329		13	20	5	2																					40
330-339	6	18	12	2	1																					39
340-349	1	23	14	2	1																					41
350-359	4	16	4	7																						31
	89	819	694	430	245	109	54	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2447

NUMBER OF RECORDS AT OR BELOW STALL SPEED (2.2 CM/SEC) 71

FREQUENCY DISTRIBUTION OF DIRECTION AND RATE

AUS Ø 3417Ø8Ø576 GMT 3(T) 973 AUSTIN CHANNEL 3 75282Ø3216 6Ø V6

DIR	2.3 TO 2.9	3 TO 6	6 TO 9	9 TO 12	12 TO 15	15 TO 18	18 TO 21	21 TO 24	24 TO 27	27 TO 3Ø	3Ø TO 33	33 TO 36	36 TO 39	39 TO 42	42 TO 45	45 TO 48	48 TO 51	51 TO 54	54 TO 57	57 TO 6Ø	6Ø TO 63	63 TO 66	66 TO 69	69 TO 72	72 TO 75	CMS/SEC
Ø- 9		1	1																							2
1Ø- 19		1																								1
2Ø- 29		1	1																							2
3Ø- 39		6																								6
4Ø- 49																										Ø
5Ø- 59	2	12	1																							15
6Ø- 69		5	9																							14
7Ø- 79		2	5																							7
8Ø- 89	3	19	9	1																						32
9Ø- 99		1Ø	16	1																						27
1ØØ-1Ø9	1	2Ø	12	1																						34
11Ø-119	4	22	27	5																						58
12Ø-129	12	48	58	19	4																					141
13Ø-139	7	29	57	57	1Ø	5																				165
14Ø-149	1	29	56	5Ø	31	5																				172
15Ø-159	2	14	28	16	9	7																				76
16Ø-169	1	9	11	3																						24
17Ø-179	1	8	1Ø																							19
18Ø-189	1	11	6	1																						19
19Ø-199	1	3																								4
2ØØ-2Ø9	1	9	5																							15
21Ø-219		8	4	1																						13
22Ø-229		5	2																							7
23Ø-239		7	3	1																						11
24Ø-249		6	4																							1Ø
25Ø-259		2	2																							4
26Ø-269	1	8	5																							14
27Ø-279		8	5																							13
28Ø-289		2	2																							4
29Ø-299		5	2	1																						8
3ØØ-3Ø9		6	6																							12
31Ø-319	1	6	4																							11
32Ø-329	1	7	3																							11
33Ø-339		1	1																							2
34Ø-349		3																								3
35Ø-359	4	3	1																							8
	44	336	356	157	54	17	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	964

NUMBER OF RECORDS AT OR BELOW STALL SPEED (2.2 CM/SEC) 9

FREQUENCY DISTRIBUTION OF DIRECTION AND RATE

AUS168 3Ø221ØØ576 GMT 3(B) 1Ø29 AUSTIN CHANNEL 3 75282Ø3216 6Ø 844TC V6

CMS/SEC

DIR	2.3 TO 2.9	3 TO 6	6 TO 9	9 TO 12	12 TO 15	15 TO 18	18 TO 21	21 TO 24	24 TO 27	27 TO 3Ø	3Ø TO 33	33 TO 36	36 TO 39	39 TO 42	42 TO 45	45 TO 48	48 TO 51	51 TO 54	54 TO 57	57 TO 6Ø	6Ø TO 63	63 TO 66	66 TO 69	69 TO 72	72 TO 75	
Ø- 9		6	2																							8
1Ø- 19	1	1																								2
2Ø- 29	1	5																								6
3Ø- 39		5																								5
4Ø- 49	1	4																								5
5Ø- 59	2	2	2																							6
6Ø- 69	1	4																								5
7Ø- 79	3	4		1																						8
8Ø- 89	1	8		1																						1Ø
9Ø- 99	2	6	6																							14
1ØØ-1Ø9	6	12	13	6	3	1																				41
11Ø-119	1	1Ø	13	18	9																					51
12Ø-129		1Ø	17	14	13	6	2																			62
13Ø-139		8	17	1Ø	8		1																			44
14Ø-149	4	15	21	2Ø	8																					68
15Ø-159	1	7	14	9	7																					38
16Ø-169	2	14	8	7	5																					36
17Ø-179	5	15	21	9	8																					58
18Ø-189	3	13	14	5	1																					36
19Ø-199	1	16	7		1																					25
2ØØ-2Ø9	3	24	7																							34
21Ø-219		15	7																							22
22Ø-229		22	5																							27
23Ø-239	2	12	9																							23
24Ø-249	2	13	7	1																						23
25Ø-259	2	7	5																							14
26Ø-269	1	15	13	2																						31
27Ø-279	1	11	16	2																						3Ø
28Ø-289	3	11	6	14	1																					35
29Ø-299	3	13	19	16	7	2																				6Ø
3ØØ-3Ø9		14	16	13	11																					54
31Ø-319		9	7	17	7	3																				43
32Ø-329	2	4	9	5	8																					28
33Ø-339		7	5	5	2																					19
34Ø-349		6	2																							8
35Ø-359		2	3																							5
		35Ø		175		12		Ø		Ø		Ø		Ø		Ø		Ø		Ø		Ø		Ø		984
	54		291		99		3		Ø		Ø		Ø		Ø		Ø		Ø		Ø		Ø		Ø	

NUMBER OF RECORDS AT OR BELOW STALL SPEED (2.2 CM/SEC) 22

FREQUENCY DISTRIBUTION OF DIRECTION AND RATE

AUS Ø 4519Ø30576 GMT 4(T) 19Ø2 AUSTIN CHANNEL 4 753Ø21Ø3Ø1Ø 6Ø V6

CMS/SEC

DIR	2.3 TO 2.9	3 TO 6	6 TO 9	9 TO 12	12 TO 15	15 TO 18	18 TO 21	21 TO 24	24 TO 27	27 TO 3Ø	3Ø TO 33	33 TO 36	36 TO 39	39 TO 42	42 TO 45	45 TO 48	48 TO 51	51 TO 54	54 TO 57	57 TO 6Ø	6Ø TO 63	63 TO 66	66 TO 69	69 TO 72	72 TO 75	
Ø- 9	3	11	4																							18
1Ø- 19	3	7	1																							11
2Ø- 29	4	6	4																							14
3Ø- 39	4	14	4																							22
4Ø- 49	5	2Ø	6	1																						32
5Ø- 59	5	21	14	3	1																					44
6Ø- 69	1	17	8	1																						27
7Ø- 79	1	19	15	4																						39
8Ø- 89	3	25	42	1Ø	1																					81
9Ø- 99	3	4Ø	39	26	1																					1Ø9
1ØØ-1Ø9		8	21	11	4																					44
11Ø-119	2	54	96	47	21	1																				221
12Ø-129	1	41	112	73	34	4																				265
13Ø-139	2	39	9Ø	79	54	12																				276
14Ø-149		34	67	65	38	11	3																			218
15Ø-159	3	17	24	28	9	4																				85
16Ø-169	2	8	8	3	1	1																				23
17Ø-179	1	19	16	3																						39
18Ø-189	4	15	13	3																						35
19Ø-199	1	6	1																							8
2ØØ-2Ø9	1	13	4	2		1																				21
21Ø-219	2	1Ø	5	2																						19
22Ø-229	3	8	4																							15
23Ø-239	1	12	8	2																						23
24Ø-249	3	12	7																							22
25Ø-259		1	2	1																						4
26Ø-269	1	8	1Ø	2																						21
27Ø-279	2	7	4																							13
28Ø-289		7	3																							1Ø
29Ø-299	3	5	6																							14
3ØØ-3Ø9		7	2																							9
31Ø-319	1	8																								9
32Ø-329	2	15	2																							19
33Ø-339	4	12	1																							17
34Ø-349		7	1																							8
35Ø-359	6	17	6																							29
		57Ø		366		34		Ø		Ø		Ø		Ø		Ø		Ø		Ø		Ø		Ø		1864
	77		65Ø		164		3		Ø		Ø		Ø		Ø		Ø		Ø		Ø		Ø		Ø	

NUMBER OF RECORDS AT OR BELOW STALL SPEED (2.2 CM/SEC) 38

FREQUENCY DISTRIBUTION OF DIRECTION AND RATE

AUS24Ø 4222100576 GMT 4(B) 1045 AUSTIN CHANNEL 4 753Ø21Ø3Ø1Ø 6Ø 118TC V6

CMS/SEC

DIR	2.3 TO 2.9	3 TO 6	6 TO 9	9 TO 12	12 TO 15	15 TO 18	18 TO 21	21 TO 24	24 TO 27	27 TO 3Ø	3Ø TO 33	33 TO 36	36 TO 39	39 TO 42	42 TO 45	45 TO 48	48 TO 51	51 TO 54	54 TO 57	57 TO 6Ø	6Ø TO 63	63 TO 66	66 TO 69	69 TO 72	72 TO 75	
Ø- 9	1	3	3		1																					8
1Ø- 19	1	2	2																							5
2Ø- 29	2	1																								3
3Ø- 39	1	2	3																							6
4Ø- 49	1	1																								2
5Ø- 59			1																							1
6Ø- 69	1		5																							6
7Ø- 79	2		2																							4
8Ø- 89		2	3	1																						6
9Ø- 99		2	4	1																						7
1ØØ-1Ø9			6	1																						7
11Ø-119	1	4	9	1	1																					16
12Ø-129		2	1Ø	5	3	1																				21
13Ø-139		6	23	8	6	1																				44
14Ø-149	1	2	9	8	5																					25
15Ø-159		4	5	7	6	1																				23
16Ø-169	2	4	9	9	5																					29
17Ø-179	2	4	9	7	4	5	2																			33
18Ø-189		4	15	16	8	8	1																			52
19Ø-199	1	4	13	9	4	6	1																			38
2ØØ-2Ø9	2	5	9	5	1	3																				25
21Ø-219	2	13	6	4	2	2																				29
22Ø-229	1	5	8	1	3	1																				19
23Ø-239		4	1Ø		1	1																				16
24Ø-249	1	6	7	3		1																				18
25Ø-259		2	5		1																					8
26Ø-269		5	5	2	1																					13
27Ø-279		3	4	3	1																					11
28Ø-289	2		4	2	1																					9
29Ø-299		6	15	4	4																					29
3ØØ-3Ø9		7	8	7	6		1																			29
31Ø-319		1	1Ø	12	4	7	2	1																		37
32Ø-329		8	9	9	15	8	5	1																		55
33Ø-339	2	2	7	4	6	7	3		1																	32
34Ø-349	1	3	1	5	1	6	2			1																2Ø
35Ø-359	2	6	3			1	1																			13
	29	123	242	134	9Ø	59	18	2	1	1	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	699

NUMBER OF RECORDS AT OR BELOW STALL SPEED (2.2 CM/SEC) 11

FREQUENCY DISTRIBUTION OF DIRECTION AND RATE

AUS Ø 5817Ø2Ø576 GMT 5(T) 998 AUSTIN CHANNEL 5 75315Ø2492 6Ø V6

CMS/SEC

DIR	2.3 TO 2.9	3 TO 6	6 TO 9	9 TO 12	12 TO 15	15 TO 18	18 TO 21	21 TO 24	24 TO 27	27 TO 3Ø	3Ø TO 33	33 TO 36	36 TO 39	39 TO 42	42 TO 45	45 TO 48	48 TO 51	51 TO 54	54 TO 57	57 TO 6Ø	6Ø TO 63	63 TO 66	66 TO 69	69 TO 72	72 TO 75	
Ø- 9	1	7	6																							14
1Ø- 19		5																								5
2Ø- 29	4	16	3																							23
3Ø- 39	4	9	4	1																						18
4Ø- 49		6	8	2																						16
5Ø- 59		9	11	2			2																			24
6Ø- 69	1	7	17	5	3	1																				34
7Ø- 79	1	6		2	1	4																				14
8Ø- 89		7	15	8	1	8	2																			41
9Ø- 99		8	16	18	12	9	2																			65
1ØØ-1Ø9		4	11	3	8	6	2																			34
11Ø-119		5	21	12	13	5																				56
12Ø-129		19	33	2Ø	14	6	2																			94
13Ø-139	2	9	24	26	1Ø	4																				75
14Ø-149	1	22	36	37	24	4																				124
15Ø-159		11	23	2Ø	5	3																				62
16Ø-169		3	6	8	1																					18
17Ø-179		1	7	6	1																					15
18Ø-189		2	11	5	3		1																			22
19Ø-199	1	2	3	2																						8
2ØØ-2Ø9		1	2																							3
21Ø-219		1	3	1																						5
22Ø-229		3																								3
23Ø-239		2																								2
24Ø-249			1																							1
25Ø-259																										Ø
26Ø-269		1	2																							3
27Ø-279		1	1																							2
28Ø-289		1	1																							2
29Ø-299		2	3	1																						6
3ØØ-3Ø9		5	7	4	2	1																				19
31Ø-319		4	14	3	3	1																				25
32Ø-329		15	16	15	7	2	1																			56
33Ø-339	2	13	11	1Ø	7	3																				46
34Ø-349	1	8	8	6	2																					25
35Ø-359	6	13	3	6	1																					29
	24	229	327	223	118	57	12	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	99Ø

NUMBER OF RECORDS AT OR BELOW STALL SPEED (2.2 CM/SEC) 8

FREQUENCY DISTRIBUTION OF DIRECTION AND RATE

AUS 54 5422100576 GMT 5(B) 148 AUSTIN CHANNEL 5 75315102492 60 304TC V6

CMS/SEC

DIR	2.3 TO 2.9	3 TO 6	6 TO 9	9 TO 12	12 TO 15	15 TO 18	18 TO 21	21 TO 24	24 TO 27	27 TO 30	30 TO 33	33 TO 36	36 TO 39	39 TO 42	42 TO 45	45 TO 48	48 TO 51	51 TO 54	54 TO 57	57 TO 60	60 TO 63	63 TO 66	66 TO 69	69 TO 72	72 TO 75	
0- 9																										0
10- 19																										0
20- 29		1																								1
30- 39			1																							1
40- 49																										0
50- 59		1	1																							2
60- 69			1	1																						2
70- 79			1		1																					2
80- 89																										0
90- 99				2																						2
100-109																										0
110-119																										0
120-129				3																						3
130-139					1																					1
140-149				2	1																					3
150-159					1		1																			2
160-169		1		1																						2
170-179						1				1																2
180-189				1	1		2	1			1															6
190-199		1	1	1		1	2																			6
200-209			1																							1
210-219			1	2	1																					4
220-229		1	1	1	3																					6
230-239				2	1																					3
240-249			1	3	5	1																				10
250-259					1	2	1	1																		5
260-269		1			1	3	3	1																		9
270-279						2	1		1	1																5
280-289		1	1				1																			3
290-299		1																								1
300-309						1	1																			2
310-319			1																							1
320-329																										0
330-339					1																					1
340-349																										0
350-359																										0
	8		19		11		3		2		0		0		0		0		0		0		0			86
	0	11		18		12		1		1		0		0		0		0		0		0		0		

NUMBER OF RECORDS AT OR BELOW STALL SPEED (2.2 CM/SEC) 0

FREQUENCY DISTRIBUTION OF DIRECTION AND RATE

CRO ø ØØ23270377 GMT 1(T) 1822 CROZIER STRAIT 1 75316 97222 6Ø 377 V6

CMS/SEC

DIR	2.3 TO 2.9	3 TO 6	6 TO 9	9 TO 12	12 TO 15	15 TO 18	18 TO 21	21 TO 24	24 TO 27	27 TO 3Ø	3Ø TO 33	33 TO 36	36 TO 39	39 TO 42	42 TO 45	45 TO 48	48 TO 51	51 TO 54	54 TO 57	57 TO 6Ø	6Ø TO 63	63 TO 66	66 TO 69	69 TO 72	72 TO 75	
ø- 9		9	14	8	8	5	5	1	2	1																53
1Ø- 19		2	4	3		1																				1Ø
2Ø- 29		1	4	1	2																					8
3Ø- 39			3	1																						4
4Ø- 49			2																							2
5Ø- 59		2	3																							5
6Ø- 69		2	1																							3
7Ø- 79		2	3																							5
8Ø- 89	1	5	2																							8
9Ø- 99		9	2																							11
1ØØ-1Ø9		9	2																							11
11Ø-119		9	8																							17
12Ø-129	3	31	8	1	1																					44
13Ø-139	5	12	3	4	1																					25
14Ø-149		5	11	14	5																					35
15Ø-159	1	7	13	2Ø	37	26	7																			111
16Ø-169	1	7	27	61	89	116	119	47	14	5																486
17Ø-179	1	11	31	52	5Ø	52	83	59	33	9	2															383
18Ø-189	1	16	36	19	9	5	7	5		1																99
19Ø-199		7	11																							18
2ØØ-2Ø9	1	9	4																							14
21Ø-219	1	6	6																							13
22Ø-229		1Ø	2																							12
23Ø-239		2	3																							5
24Ø-249		4	3																							7
25Ø-259	1	6	3	1																						11
26Ø-269	3	1	1																							5
27Ø-279	1	1	4																							6
28Ø-289		1	6																							7
29Ø-299		1	2																							3
3ØØ-3Ø9		2	3	1																						6
31Ø-319	3	5	7	6																						21
32Ø-329		4	25	21	7	1	1																			59
33Ø-339		6	3Ø	41	27	19	8	15	3																	149
34Ø-349		9	4	9	4	6	9	1	3	1																46
35Ø-359	1	1Ø	14	21	17	14	14	11	4	1																1Ø7
	24	223	3Ø6	284	258	245	253	14Ø	59	18	2	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	1812

NUMBER OF RECORDS AT OR BELOW STALL SPEED (2.2 CM/SEC) 1Ø

FREQUENCY DISTRIBUTION OF DIRECTION AND RATE

CRO 25 Ø122280377 GMT 1(M) 1799 CROZIER STRAIT 1 75316 97222 6Ø 627TC V6

DIR	2.3 TO 2.9	3 TO 6	6 TO 9	9 TO 12	12 TO 15	15 TO 18	18 TO 21	21 TO 24	24 TO 27	27 TO 3Ø	3Ø TO 33	33 TO 36	36 TO 39	39 TO 42	42 TO 45	45 TO 48	48 TO 51	51 TO 54	54 TO 57	57 TO 6Ø	6Ø TO 63	63 TO 66	66 TO 69	69 TO 72	72 TO 75	CMS/SEC
Ø- 9		14	11	11	21	15	15	17	13	6	8	4	1			1										137
1Ø- 19	2	6	7	5	12	9	6	4	1																	52
2Ø- 29		14	6	5	7	5	2																			39
3Ø- 39		3	4	5	6	2																				2Ø
4Ø- 49		3	3		2																					8
5Ø- 59	1	2	2	1																						6
6Ø- 69		3	4		1																					8
7Ø- 79		1																								1
8Ø- 89			2																							2
9Ø- 99		4	4																							8
1ØØ-1Ø9		1																								1
11Ø-119		5	3	1																						9
12Ø-129		2	3	1																						6
13Ø-139		6	2																							8
14Ø-149	3	13	1Ø	3	2																					31
15Ø-159	2	25	19	25	18	6	1																			96
16Ø-169	1	12	34	39	34	42	29	21	6	4																222
17Ø-179		17	11	22	44	55	9Ø	84	78	45	34	2Ø	2													502
18Ø-189	1	7	6	14	19	39	33	58	38	26	15	4	2													262
19Ø-199		3	3	5	8	3	1																			23
2ØØ-2Ø9			4	2																						6
21Ø-219	2	4	2	1																						9
22Ø-229		1	1																							2
23Ø-239		3	1																							4
24Ø-249	1		1																							2
25Ø-259																										Ø
26Ø-269																										Ø
27Ø-279			1																							1
28Ø-289		1																								1
29Ø-299		1	2																							3
3ØØ-3Ø9		1	1																							2
31Ø-319		2		1																						3
32Ø-329	1	1	2																							4
33Ø-339		3	2		1																					6
34Ø-349		5	6	8	7	1		1	2	4			2													36
35Ø-359	3	21	21	26	29	22	2Ø	21	21	13	17	11	12	7	4	1										249
	17	184	18Ø	176	212	2ØØ	199	2Ø8	159	98	74	4Ø	19	7	4	2	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	1779

NUMBER OF RECORDS AT OR BELOW STALL SPEED (2.2 CM/SEC) 2Ø

FREQUENCY DISTRIBUTION OF DIRECTION AND RATE

CRO 62 030127037 7 GMT 1(B) 429 CROZIER STRAIT 1 75316 97222 60 568TC V6

CMS/SEC

DIR	2.3 TO 2.9	3 TO 6	6 TO 9	9 TO 12	12 TO 15	15 TO 18	18 TO 21	21 TO 24	24 TO 27	27 TO 30	30 TO 33	33 TO 36	36 TO 39	39 TO 42	42 TO 45	45 TO 48	48 TO 51	51 TO 54	54 TO 57	57 TO 60	60 TO 63	63 TO 66	66 TO 69	69 TO 72	72 TO 75	
0- 9		3	1																							4
10- 19																										0
20- 29		2					1																			3
30- 39		1																								1
40- 49																										0
50- 59	1																									1
60- 69		4																								4
70- 79			1																							1
80- 89		2																								2
90- 99		1	1																							2
100-109		1	2	1																						4
110-119	1	2	6	5	2		1																			17
120-129		4	4		2	2	2																			14
130-139		1	9	2	10	12	2	1																		37
140-149		2	8	20	16	10	8	2	1																	67
150-159		2	3	10	14	7	5	3																		44
160-169			5	10	7	9	5	2																		38
170-179		4	1	2	2	4																				13
180-189			1	3	3																					7
190-199		2	1	1			1																			5
200-209		2	2																							4
210-219																										0
220-229																										0
230-239		1	1																							2
240-249			2																							2
250-259			3																							3
260-269		1	3																							4
270-279																										0
280-289		2	3																							5
290-299			4	3																						7
300-309		1	6	5																						12
310-319	1	2	10	5	3																					21
320-329		4	5	7	4	1	2																			23
330-339	1	5	12	15	4	4	2																			43
340-349		4	5	6	5	3	2																			25
350-359		3	2	2	4		1																			12
	4	56	101	97	76	52	32	8	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	427

NUMBER OF RECORDS AT OR BELOW STALL SPEED (2.2 CM/SEC) 2

FREQUENCY DISTRIBUTION OF DIRECTION AND RATE

CRO Ø Ø6Ø23ØØ377 GMT 2(T) 1767 CROZIER STRAIT 2 74315 97198 6Ø 563 V6

DIR	2.3 TO 2.9	3 TO 6	6 TO 9	9 TO 12	12 TO 15	15 TO 18	18 TO 21	21 TO 24	24 TO 27	27 TO 3Ø	3Ø TO 33	33 TO 36	36 TO 39	39 TO 42	42 TO 45	45 TO 48	48 TO 51	51 TO 54	54 TO 57	57 TO 6Ø	6Ø TO 63	63 TO 66	66 TO 69	69 TO 72	72 TO 75	CMS/SEC
Ø- 9	2	11	17	17	7	6	4	1																		65
1Ø- 19		7	3	5	1																					16
2Ø- 29	2	8	21	12	5																					48
3Ø- 39	1	8	27	7	1																					44
4Ø- 49		4	11	6																						21
5Ø- 59		7	12	7																						26
6Ø- 69		5	5	1																						11
7Ø- 79		4	12	3																						19
8Ø- 89		2	1Ø	7	1																					2Ø
9Ø- 99	1	1	8	4	1																					15
1ØØ-1Ø9		3	7	2	1																					13
11Ø-119		4	9	5	8																					26
12Ø-129	2	4	4	12	16	1	1																			4Ø
13Ø-139	1	7	1Ø	14	27	7																				66
14Ø-149		1	13	32	51	38	16	4																		155
15Ø-159	2	18	23	57	39	3Ø	24	6	1																	2ØØ
16Ø-169	3	37	44	27	19	9	1Ø	9	3																	161
17Ø-179	3	28	1Ø	1Ø	8	3	3	4	1																	7Ø
18Ø-189	2	12	11	13	6	2			3																	49
19Ø-199		5	4	1	6																					16
2ØØ-2Ø9		4	5	6																						15
21Ø-219		1	7	1	1	1																				11
22Ø-229		3	3	1																						7
23Ø-239		2	2																							4
24Ø-249		2	2																							4
25Ø-259			3	2	1																					6
26Ø-269		3	2																							5
27Ø-279		6	2	1																						9
28Ø-289		3	2	1																						6
29Ø-299		4	4	1																						9
3ØØ-3Ø9	1	4	6	1																						12
31Ø-319	1	9	1Ø	4		1																				25
32Ø-329	2	14	13	3Ø	13	2	7	2	2																	85
33Ø-339		6	28	5Ø	82	67	41	4Ø	19	1Ø	3															348
34Ø-349		5	8	9	2	7	5		1																	37
35Ø-359	1	19	21	12	2Ø	12	1Ø	2																		97
	24	264	38Ø	361	316	187	121	68	3Ø	1Ø	3	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	1764

NUMBER OF RECORDS AT OR BELOW STALL SPEED (2.2 CM/SEC) 3

FREQUENCY DISTRIBUTION OF DIRECTION AND RATE

CRO 25 Ø719300377 GMT 2(M) 1750 CROZIER STRAIT 2 74315 97198 60 66TC V6

DIR	2.3 TO 2.9	3 TO 6	6 TO 9	9 TO 12	12 TO 15	15 TO 18	18 TO 21	21 TO 24	24 TO 27	27 TO 30	30 TO 33	33 TO 36	36 TO 39	39 TO 42	42 TO 45	45 TO 48	48 TO 51	51 TO 54	54 TO 57	57 TO 60	60 TO 63	63 TO 66	66 TO 69	69 TO 72	72 TO 75	CMS/SEC
Ø- 9	3	7	15	19	35	32	51	27	30	28	17	9	4	6												283
10- 19	1	7	25	29	16	18	9	17	9	10	2	2														145
20- 29	1	8	8	14	11	3	7	2																		54
30- 39	1	5	15	6	8	1																				36
40- 49		6	14	11	6																					37
50- 59		3	7	8																						18
60- 69		3	4	9	1																					17
70- 79	2	4	1	5	1																					13
80- 89		3	5	11	1																					20
90- 99		6	2	9	1	1																				19
100-109		2	3	4																						9
110-119		1	5	6	4																					16
120-129	2	7	4	7	4	6	1																			31
130-139		2	2	1	7	7	2																			21
140-149		4	2	2	5	3	6	3																		25
150-159	1	9	3	4	4	10	14	9	1	2																57
160-169		18	6	10	8	6	11	12	6	2																79
170-179		22	20	25	34	27	44	37	17	30	10	3														269
180-189	1	23	11	21	10	9	13	19	19	12	14	8														160
190-199	2	6	1	3	2	1	3	4	1		1															24
200-209	1	9	3	4	2	3	5	1	2	3	2															35
210-219		6	7	7	4	5	1	1																		31
220-229		4	8	8	1	3																				24
230-239		3	3	1	1																					8
240-249		4	2	5	1																					12
250-259		5	5	4																						14
260-269		2	2	3	1																					8
270-279		1	5		1																					7
280-289			1																							1
290-299		2	6																							8
300-309	1	2	4	2																						9
310-319		2	2	3																						7
320-329		4	6	8																						18
330-339		3	5	3	2																					13
340-349		2	9	14	5	2	2	1																		35
350-359		6	11	20	21	17	16	15	8	13	13	10	14	4												168
	201		286		157		151		106		32		10		Ø		Ø		Ø		Ø		Ø		Ø	1749
	16	235		197		185		94		61		18		Ø		Ø		Ø		Ø		Ø		Ø		

NUMBER OF RECORDS AT OR BELOW STALL SPEED (2.2 CM/SEC) 1

FREQUENCY DISTRIBUTION OF DIRECTION AND RATE

CRO 52 Ø918292Ø377 GMT 2(B) 2259 CROZIER STRAIT 2 74315 97198 6Ø 6Ø3TC V6

CMS/SEC

DIR	2.3 TO 2.9	3 TO 6	6 TO 9	9 TO 12	12 TO 15	15 TO 18	18 TO 21	21 TO 24	24 TO 27	27 TO 3Ø	3Ø TO 33	33 TO 36	36 TO 39	39 TO 42	42 TO 45	45 TO 48	48 TO 51	51 TO 54	54 TO 57	57 TO 6Ø	6Ø TO 63	63 TO 66	66 TO 69	69 TO 72	72 TO 75	
Ø- 9	1	7	21	39	43	28	3Ø	1Ø	1																	18Ø
1Ø- 19	2	5	12	12	8	5	4	3	4																	55
2Ø- 29		4	8	1Ø	5	3	2	1																		33
3Ø- 39	2	5	5	11	7				2																	32
4Ø- 49		2	8	6	2																					18
5Ø- 59			7	8	2																					17
6Ø- 69	1	1	7	12	5	1																				27
7Ø- 79			4	4	2		1																			11
8Ø- 89		3	1	4	6	4																				18
9Ø- 99			4	6	7	2	2																			21
1ØØ-1Ø9	2	1	1	9	7	7	4																			31
11Ø-119		1	1	9	1Ø	18	6	1	1																	47
12Ø-129	3	1		5	12	17	11	4	4		2															59
13Ø-139	2	1		5	13	18	19	13	5	2	1															79
14Ø-149	2	1	2	5	18	21	26	9	7		1															92
15Ø-159	1	6	7	24	38	36	29	15	1Ø	5																171
16Ø-169	1	9	14	29	23	6	8	7	1Ø	3	2															112
17Ø-179	3	11	16	15	6	2	3	11	9	3	1	1	1													82
18Ø-189	3	2Ø	8	8	3	4	1Ø	1Ø	6	4	2	1														79
19Ø-199	4	8	6	7	4	1	1	9	3	2	2															47
2ØØ-2Ø9	1	4	7	11	2	2	5			1																33
21Ø-219		2	4	4	3	1	1																			15
22Ø-229		4	2	6	2																					14
23Ø-239		1	3	1	4																					9
24Ø-249		8	4	2				1																		15
25Ø-259		1	3	1																						5
26Ø-269	1	4	1	2																						8
27Ø-279	3	7	4	3																						17
28Ø-289	3	2	7	1																						13
29Ø-299		4	4	3																						11
3ØØ-3Ø9		3	3	8																						14
31Ø-319	2	9	9	8																						28
32Ø-329	2	9	12	7	4	1		1	1																	37
33Ø-339	3	1Ø	11	1Ø	7	1	5	4																		51
34Ø-349	6	1Ø	17	22	27	19	22	3	3	1																13Ø
35Ø-359		25	36	61	63	39	37	13	5																	279
	48	189	261	382	337	241	227	116	71	21	11	2	1	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	19Ø7

NUMBER OF RECORDS AT OR BELOW STALL SPEED (2.2 CM/SEC) 352

FREQUENCY DISTRIBUTION OF DIRECTION AND RATE

CRO Ø 12Ø413Ø477 GMT 3(T) 1439 CROZIER STRAIT 3 75305 97104 60 98 V6

CMS/SEC

DIR	2.3 TO 2.9	3 TO 6	6 TO 9	9 TO 12	12 TO 15	15 TO 18	18 TO 21	21 TO 24	24 TO 27	27 TO 3Ø	3Ø TO 33	33 TO 36	36 TO 39	39 TO 42	42 TO 45	45 TO 48	48 TO 51	51 TO 54	54 TO 57	57 TO 6Ø	6Ø TO 63	63 TO 66	66 TO 69	69 TO 72	72 TO 75	
Ø- 9																										Ø
1Ø- 19		2																								2
2Ø- 29																										Ø
3Ø- 39																										Ø
4Ø- 49																										Ø
5Ø- 59		1																								Ø
6Ø- 69																										1
7Ø- 79																										Ø
8Ø- 89																										Ø
9Ø- 99																										Ø
1ØØ-1Ø9																										Ø
11Ø-119																										Ø
12Ø-129																										Ø
13Ø-139																										Ø
14Ø-149																										Ø
15Ø-159					1																					1
16Ø-169				3	5																					8
17Ø-179					8	2	4	2																		16
18Ø-189	34	19Ø	31Ø	289	193	13Ø	1Ø3	78	39	12																1378
19Ø-199			1	2	3	1																				7
2ØØ-2Ø9		1	1																							2
21Ø-219		1	1																							2
22Ø-229	1																									1
23Ø-239																										Ø
24Ø-249																										Ø
25Ø-259																										Ø
26Ø-269																										Ø
27Ø-279																										Ø
28Ø-289		1																								1
29Ø-299																										Ø
3ØØ-3Ø9		1																								1
31Ø-319																										Ø
32Ø-329																										Ø
33Ø-339																										Ø
34Ø-349																										Ø
35Ø-359		2																								2
	35	199	313	294	21Ø	133	1Ø7	8Ø	39	12	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	1422

NUMBER OF RECORDS AT OR BELOW STALL SPEED (2.2 CM/SEC) 17

FREQUENCY DISTRIBUTION OF DIRECTION AND RATE

CRO 92 16Ø113Ø477 GMT 3(B) 2833 CROZIER STRAIT 3 753Ø5 971Ø4 6Ø 29T V6

CMS/SEC

DIR	2.3 TO 2.9	3 TO 6	6 TO 9	9 TO 12	12 TO 15	15 TO 18	18 TO 21	21 TO 24	24 TO 27	27 TO 3Ø	3Ø TO 33	33 TO 36	36 TO 39	39 TO 42	42 TO 45	45 TO 48	48 TO 51	51 TO 54	54 TO 57	57 TO 6Ø	6Ø TO 63	63 TO 66	66 TO 69	69 TO 72	72 TO 75	
Ø- 9		29	23	22	2Ø	11	13	7	4	1																13Ø
1Ø- 19	3	16	17	16	18	9	9	7	2	1																98
2Ø- 29	5	1Ø	4	14	6	6	9	1Ø	1	1																66
3Ø- 39		12	4	3	2	3	2	1	2		1															3Ø
4Ø- 49	2	5	4	3	1	2	1		1	1																2Ø
5Ø- 59	1	2	2																							5
6Ø- 69	1	8	5	2	1																					17
7Ø- 79		4	4																							8
8Ø- 89	1	3	4	1	1	1																				11
9Ø- 99	1	1Ø	5	1	1	2																				2Ø
1ØØ-1Ø9	1	5	4		2		1																			13
11Ø-119	1	14	11	6	3	2																				37
12Ø-129	4	16	17	22	8	1	2	1			1															72
13Ø-139	3	17	26	23	2Ø	6	7	4	5																	111
14Ø-149		25	44	4Ø	48	26	19	11	5	3																221
15Ø-159	1	29	4Ø	66	53	37	32	21	9	4																292
16Ø-169	1	25	44	69	66	57	44	21	13	1																341
17Ø-179	2	24	47	73	86	6Ø	4Ø	24	9	1																366
18Ø-189	4	18	45	45	71	61	18	14	1																	277
19Ø-199	1	1Ø	18	28	3Ø	1Ø	9	5	1		1															113
2ØØ-2Ø9		13	12	25	12	3	1		2	1																69
21Ø-219	2	1Ø	14	1Ø	11	1		1																		49
22Ø-229		8	8	5																						21
23Ø-239	1	4	3	1	1																					1Ø
24Ø-249	3	2	5	2	1																					13
25Ø-259	1	7	6	2																						16
26Ø-269	1	4	1																							6
27Ø-279		6	2	1	1																					1Ø
28Ø-289		5	5																							1Ø
29Ø-299		4	6	1	1																					12
3ØØ-3Ø9	1	6	7	4	2			1	1																	22
31Ø-319	3	8	14	4	1	1																				31
32Ø-329	1	11	8	2	2		1																			25
33Ø-339		21	36	13	6	9	2	1	2																	9Ø
34Ø-349	3	16	18	12	3	1	3	3	4																	63
35Ø-359		14	32	34	18	11	6	5	1																	121
	48	421	546	552	496	322	219	137	63	14	3	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	2821

NUMBER OF RECORDS AT OR BELOW STALL SPEED (2.2 CM/SEC) 12

FREQUENCY DISTRIBUTION OF DIRECTION AND RATE

CRO Ø 2ØØ61ØØ477 GMT 4(T) 1573 CROZIER STRAIT 753Ø3 97Ø8Ø 6Ø 178 V6

DIR	2.3 TO 2.9	3 TO 6	6 TO 9	9 TO 12	12 TO 15	15 TO 18	18 TO 21	21 TO 24	24 TO 27	27 TO 3Ø	3Ø TO 33	33 TO 36	36 TO 39	39 TO 42	42 TO 45	45 TO 48	48 TO 51	51 TO 54	54 TO 57	57 TO 6Ø	6Ø TO 63	63 TO 66	66 TO 69	69 TO 72	72 TO 75	
CMS/SEC																										
Ø- 9		6	5	5	6	6																				28
1Ø- 19	2	1	1	1	2																					7
2Ø- 29	3	4	2	7	7	1																				24
3Ø- 39	2	11			1																					14
4Ø- 49	2	3	2	1	1																					9
5Ø- 59	1	7	1	1																						1Ø
6Ø- 69	1	5	1																							7
7Ø- 79	1	8	5																							14
8Ø- 89	2	5		1																						8
9Ø- 99	1	5	2																							8
1ØØ-1Ø9	1	6																								7
11Ø-119	3	1																								4
12Ø-129		6	5																							11
13Ø-139		7	2																							9
14Ø-149	1	1Ø	9																							2Ø
15Ø-159		17	13	4	4	1																				39
16Ø-169	3	26	28	22	16	4	1	1																		1Ø1
17Ø-179	3	2Ø	51	73	84	52	48	24	3	1																359
18Ø-189	4	19	57	74	11Ø	1Ø3	97	54	25	1Ø																553
19Ø-199	2	17	25	2Ø	15	15	7	4																		1Ø5
2ØØ-2Ø9	3	6	15	5			1																			3Ø
21Ø-219	1	7	5	3	1																					17
22Ø-229	3	6	1																							1Ø
23Ø-239	2	8	2																							12
24Ø-249		4																								4
25Ø-259	1		1																							2
26Ø-269	1	4																								5
27Ø-279			1																							1
28Ø-289	2	3																								5
29Ø-299			2																							2
3ØØ-3Ø9	2	4	1																							7
31Ø-319		5	4	1																						1Ø
32Ø-329	3	8	6	1				4																		22
33Ø-339		4	2	3	4	5	4	4																		26
34Ø-349	1		3	1		3	1																			9
35Ø-359		7	5	3	4	5	2																			26
	25Ø		227		195		91		11		Ø		Ø		Ø		Ø		Ø		Ø		Ø		Ø	1526
	51	257		255		161		28		Ø		Ø		Ø		Ø		Ø		Ø		Ø		Ø		

NUMBER OF RECORDS AT OR BELOW STALL SPEED (2.2 CM/SEC) 47

FREQUENCY DISTRIBUTION OF DIRECTION AND RATE

CRO2ØØ 22ØØ12Ø477 GMT 4(M) 1533 CROZIER STRAIT 75303 97080 6Ø 453TCPV6

CMS/SEC

DIR	2.3 TO 2.9	3 TO 6	6 TO 9	9 TO 12	12 TO 15	15 TO 18	18 TO 21	21 TO 24	24 TO 27	27 TO 3Ø	3Ø TO 33	33 TO 36	36 TO 39	39 TO 42	42 TO 45	45 TO 48	48 TO 51	51 TO 54	54 TO 57	57 TO 6Ø	6Ø TO 63	63 TO 66	66 TO 69	69 TO 72	72 TO 75	
Ø- 9	1	8	12	16	16	13	13	4	4	5	1															93
1Ø- 19	1	9	9	9	15	9	4	8	1Ø	1																75
2Ø- 29		9	9	8	1Ø	2	5	6	3	1																53
3Ø- 39		7	9	5	2	1	2	3																		29
4Ø- 49	1				2	2																				5
5Ø- 59		3	4	1	1																					9
6Ø- 69		1	1	1																						3
7Ø- 79		6		2																						8
8Ø- 89		3	1	2																						6
9Ø- 99	1	3																								4
1ØØ-1Ø9		2	1																							3
11Ø-119		6	1																							7
12Ø-129		9	3																							12
13Ø-139	1	3																								4
14Ø-149	1	6	4																							11
15Ø-159		8	9	2																						19
16Ø-169	1	11	5	1																						18
17Ø-179	2	22	14	14	1																					53
18Ø-189	1	26	46	32	1Ø	1	3	1																		12Ø
19Ø-199	1	44	38	56	55	18	19	12	6	4	1															254
2ØØ-2Ø9	3	17	28	33	34	22	25	13	7	4	3															189
21Ø-219	3	8	16	25	13	8	1	2																		76
22Ø-229	1	1Ø	13	9		2																				35
23Ø-239	2	8	4		1																					15
24Ø-249		11	2	2																						15
25Ø-259		13		1																						14
26Ø-269		11		1																						12
27Ø-279		4	3	1																						8
28Ø-289	2	7	1																							1Ø
29Ø-299	1	8	1																							1Ø
3ØØ-3Ø9	2	9	3																							14
31Ø-319	1	6	5	1																						13
32Ø-329	1	9	8	4																						22
33Ø-339	1	13	9	4		2																				29
34Ø-349	1	15	24	21	1Ø	9	3	1		1																85
35Ø-359	2	23	27	35	25	18	12	7	1	2	2															154
		359		288		1Ø7		57		18		Ø		Ø		Ø		Ø		Ø		Ø		Ø		1491
	31		311		195		87		31		7		Ø		Ø		Ø		Ø		Ø		Ø		Ø	

NUMBER OF RECORDS AT OR BELOW STALL SPEED (2.2 CM/SEC) 42

FREQUENCY DISTRIBUTION OF DIRECTION AND RATE

CRO278 240909ØØ477 GMT 4(B) 8319 CROZIER STRAIT 4 753Ø3 97Ø8Ø 6Ø 443TC V6

DIR	2.3 TO 2.9	3 TO 6	6 TO 9	9 TO 12	12 TO 15	15 TO 18	18 TO 21	21 TO 24	24 TO 27	27 TO 3Ø	3Ø TO 33	33 TO 36	36 TO 39	39 TO 42	42 TO 45	45 TO 48	48 TO 51	51 TO 54	54 TO 57	57 TO 6Ø	6Ø TO 63	63 TO 66	66 TO 69	69 TO 72	72 TO 75	
CMS/SEC																										
Ø- 9	18	25	32	63	71	53	25	14	7	1																3Ø9
1Ø- 19	2Ø	49	49	85	119	79	41	16		1	1															46Ø
2Ø- 29	22	6Ø	48	113	1Ø2	81	44	17	4	1																492
3Ø- 39	19	51	68	7Ø	84	48	26	12	4	3																385
4Ø- 49	19	37	6Ø	77	1Ø1	36	23	5	6		1															365
5Ø- 59	18	34	51	92	82	33	2Ø	13		1																344
6Ø- 69	7	17	28	44	38	15	7	6	1	4	1															168
7Ø- 79	14	22	54	6Ø	44	23	7	7	1																	232
8Ø- 89	8	28	39	58	21	8	6	2	1	3	1															175
9Ø- 99	6	18	3Ø	41	14	4	1		2																	116
1ØØ-1Ø9	4	18	27	27	5	2	1																			84
11Ø-119	12	26	28	11	3	2																				82
12Ø-129	1Ø	21	18	11	1																					61
13Ø-139	5	15	19	6	1																					46
14Ø-149	6	18	21	6																						51
15Ø-159	22	27	23	9	2																					83
16Ø-169	27	62	36	37	1Ø	8																				18Ø
17Ø-179	34	71	66	54	39	32	4	2	1																	3Ø3
18Ø-189	33	65	46	54	44	27	6	1																		276
19Ø-199	45	69	59	5Ø	52	29	14	5	1																	324
2ØØ-2Ø9	35	68	57	53	39	1Ø	4	2																		268
21Ø-219	8	18	13	13	6	3	1																			62
22Ø-229	7	22	12	7	1	1																				5Ø
23Ø-239	6	11	7	2	1																					27
24Ø-249	3	6	2																							11
25Ø-259	3	6	6																							15
26Ø-269	2	3			1																					6
27Ø-279	1	5																								6
28Ø-289	2	2																								4
29Ø-299	3	7																								1Ø
3ØØ-3Ø9	3	2	1																							6
31Ø-319		3		2																						5
32Ø-329		3	4																							7
33Ø-339	2	3	4	1																						1Ø
34Ø-349	4	9	4	4	6	1																				28
35Ø-359	6	14	11	24	26	21	4	2	2																	11Ø
	434	916	925	1Ø79	915	52Ø	234	1Ø4	3Ø	14	4	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	5175

NUMBER OF RECORDS AT OR BELOW STALL SPEED (2.2 CM/SEC) 3144

FREQUENCY DISTRIBUTION OF DIRECTION AND RATE

CRO ø 282øø6ø477 GMT 5(T) 16ø7 CROZIER STRAIT 753øø 97ø51 6ø 864 V6

CMS/SEC

DIR	2.3 TO 2.9	3 TO 6	6 TO 9	9 TO 12	12 TO 15	15 TO 18	18 TO 21	21 TO 24	24 TO 27	27 TO 3ø	3ø TO 33	33 TO 36	36 TO 39	39 TO 42	42 TO 45	45 TO 48	48 TO 51	51 TO 54	54 TO 57	57 TO 6ø	6ø TO 63	63 TO 66	66 TO 69	69 TO 72	72 TO 75	
ø- 9		6	8	4	1	2	1																			22
1ø- 19	2	1	3	4	3	1																				14
2ø- 29	2	2	4	3	1																					12
3ø- 39		8	9	1	2																					2ø
4ø- 49	1	1ø	6																							17
5ø- 59	2	7	4	1																						14
6ø- 69		2	2																							4
7ø- 79		5																								5
8ø- 89		2	3																							5
9ø- 99	1	3	2																							6
1øø-1ø9	2	5	2																							9
11ø-119		2	2																							4
12ø-129		4	4	1																						9
13ø-139	2	7	1	4	1																					15
14ø-149	2	6	11	4	5	1																				29
15ø-159	3	18	17	16	6	11	3																			74
16ø-169	7	15	43	38	4ø	27	21	5																		196
17ø-179	2	2ø	48	67	92	82	59	25	1ø																	4ø5
18ø-189	5	27	46	88	1ø1	97	47	27	1ø	5																453
19ø-199	4	14	19	14	16	5	3																			75
2øø-2ø9		6	14	6	3	1																				3ø
21ø-219	1	5	2	4	2																					14
22ø-229		5	3	2																						1ø
23ø-239		4	4																							8
24ø-249		3	1																							4
25ø-259		1	2																							3
26ø-269	2	1		1																						4
27ø-279	1	2	2																							5
28ø-289		1	1																							2
29ø-299	1	1	1																							3
3øø-3ø9	1	8	3																							12
31ø-319		6	5	1																						12
32ø-329	1	5	5	5		1	1																			18
33ø-339		3	7	9	8																					27
34ø-349	1		4	7	3																					15
35ø-359			9	3		1	2																			15
	215		283		229		57		5		ø		ø		ø		ø		ø		ø		ø		ø	1571
	43	298		284		137		2ø		ø		ø		ø		ø		ø		ø		ø		ø		

NUMBER OF RECORDS AT OR BELOW STALL SPEED (2.2 CM/SEC) 36

FREQUENCY DISTRIBUTION OF DIRECTION AND RATE

CRO 75 3018070477 GMT 5(M) 1609 CROZIER STRAIT 75300 97051 60 259TC V6

CMS/SEC

DIR	2.3 TO 2.9	3 TO 6	6 TO 9	9 TO 12	12 TO 15	15 TO 18	18 TO 21	21 TO 24	24 TO 27	27 TO 30	30 TO 33	33 TO 36	36 TO 39	39 TO 42	42 TO 45	45 TO 48	48 TO 51	51 TO 54	54 TO 57	57 TO 60	60 TO 63	63 TO 66	66 TO 69	69 TO 72	72 TO 75	
0- 9	3	17	25	26	15	10	15	7	8	1																127
10- 19	2	10	17	4	5	2	2	2	1																	45
20- 29	4	15	5	6	3	2																				35
30- 39	1	7	2	2	4		1																			17
40- 49	2	3	5																							10
50- 59		2	4																							6
60- 69		5	2																							7
70- 79		5	2	2																						9
80- 89	1	3	4																							8
90- 99	1	1	1																							3
100-109		2																								2
110-119		4	1																							5
120-129		1	2																							3
130-139		4	3																							7
140-149	1	7	2	1																						11
150-159	3	12	4	2																						21
160-169	1	3	10	9	1																					24
170-179	2	7	22	17	12	5	1																			66
180-189	1	13	34	46	49	37	32	21	3																	236
190-199	2	12	45	65	87	62	56	50	39	17	3															438
200-209	1	8	25	39	33	19	10	5	2	2																144
210-219	1	12	21	18	7	7	1	1																		68
220-229	2	8	9	6	2	1																				28
230-239	3	4	7	4																						18
240-249	1	3	4	3	1																					12
250-259	2	4	4																							10
260-269	1	4	1	1																						7
270-279	1	4	1	3	1																					10
280-289		8	3	2	2	1																				16
290-299	1	3	2																							6
300-309		4	2	1																						7
310-319	3	4	4	1																						12
320-329	1	9	4																							14
330-339	2	12	5	4		2																				25
340-349	3	13	13	7	1	5		2																		44
350-359		10	16	14	9	7	5	5	6	1																79
	46	249	312	285	232	161	123	95	59	21	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1586

NUMBER OF RECORDS AT OR BELOW STALL SPEED (2.2 CM/SEC) 23

FREQUENCY DISTRIBUTION OF DIRECTION AND RATE

CRO2ØØ 3ØØØØ7Ø477 GMT 5(M) 1634 CROZIER STRAIT 753ØØ 97Ø51 6Ø 269TCPV6

CMS/SEC

DIR	2.3 TO 2.9	3 TO 6	6 TO 9	9 TO 12	12 TO 15	15 TO 18	18 TO 21	21 TO 24	24 TO 27	27 TO 3Ø	3Ø TO 33	33 TO 36	36 TO 39	39 TO 42	42 TO 45	45 TO 48	48 TO 51	51 TO 54	54 TO 57	57 TO 6Ø	6Ø TO 63	63 TO 66	66 TO 69	69 TO 72	72 TO 75	
Ø- 9	3	23	33	38	38	24	13	9	13	11	1															2Ø6
1Ø- 19	3	25	24	14	11	6	3	3	4																	93
2Ø- 29	2	14	6	4	2	1																				29
3Ø- 39	2	7	7	3	2	4																				25
4Ø- 49	3	9	3	4																						19
5Ø- 59	1	4	3	1	1																					1Ø
6Ø- 69	2	1Ø	2	1																						15
7Ø- 79	4	7	1	1																						13
8Ø- 89	1	8	1	3																						13
9Ø- 99	3	8	1																							12
1ØØ-1Ø9	2	6	3																							11
11Ø-119	3	11	2																							16
12Ø-129	5	1Ø	2																							17
13Ø-139	5	12	1																							18
14Ø-149	1	7	4																							12
15Ø-159	4	14	14	2																						34
16Ø-169	3	2Ø	25	9	1																					58
17Ø-179	1	23	18	19	3	2	1		1																	68
18Ø-189	6	28	32	33	27	15	7	8	1	1																158
19Ø-199	3	37	46	43	33	36	18	7																		223
2ØØ-2Ø9	5	23	26	7	7	8	2																			78
21Ø-219	3	8	1Ø	6	1																					28
22Ø-229	2	6	8	2																						18
23Ø-239	4	8	1	1																						14
24Ø-249	3	8	3	1																						15
25Ø-259		2	1	1																						4
26Ø-269	2	3	5																							1Ø
27Ø-279		5	1																							6
28Ø-289	3	5																								8
29Ø-299		5	2																							7
3ØØ-3Ø9	1	4	1																							6
31Ø-319	3	8	2																							13
32Ø-329	2	7	5																							14
33Ø-339	2	7	3	1	1																					14
34Ø-349	3	2Ø	2Ø	9	5	2	1	1																		61
35Ø-359	4	31	36	39	42	32	25	15	7	3	1															235
	94	433	356	242	177	13Ø	7Ø	45	26	15	2	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	159Ø

NUMBER OF RECORDS AT OR BELOW STALL SPEED (2.2 CM/SEC) 44

FREQUENCY DISTRIBUTION OF DIRECTION AND RATE

CR0317 3200005047 7 GMT 5(B) 8405 CROZIER STRAIT 5 753ØØ 97Ø51 6Ø 586TC V6

CMS/SEC

DIR	2.3 TO 2.9	3 TO 6	6 TO 9	9 TO 12	12 TO 15	15 TO 18	18 TO 21	21 TO 24	24 TO 27	27 TO 3Ø	3Ø TO 33	33 TO 36	36 TO 39	39 TO 42	42 TO 45	45 TO 48	48 TO 51	51 TO 54	54 TO 57	57 TO 6Ø	6Ø TO 63	63 TO 66	66 TO 69	69 TO 72	72 TO 75	
Ø- 9	13	62	98	33	9	2	2	5	3	2			1													23Ø
1Ø- 19	9	5Ø	49	2Ø	3			2	1	1	1															136
2Ø- 29	11	57	49	23	2					1			1													144
3Ø- 39	21	58	58	7	1																					145
4Ø- 49	19	69	49	11	4																					152
5Ø- 59	12	57	46	9	1																					125
6Ø- 69	11	57	25	1Ø																						1Ø3
7Ø- 79	12	75	45	9	1																					142
8Ø- 89	11	62	39	13	2																					127
9Ø- 99	24	99	63	1Ø	1																					197
1ØØ-1Ø9	15	56	47	17	3	2																				14Ø
11Ø-119	17	7Ø	63	26	4	2	3																			185
12Ø-129	19	97	116	45	18	2	2	1																		3ØØ
13Ø-139	13	1Ø1	111	63	27	13	4	2																		334
14Ø-149	17	84	13Ø	84	56	16	6	2	2																	397
15Ø-159	27	115	184	124	6Ø	24	8		1																	543
16Ø-169	15	74	96	43	25	7	2																			262
17Ø-179	7	35	44	1Ø	2	1	1	1																		1Ø1
18Ø-189	8	21	13	2	1	2																				47
19Ø-199	2	18	7	1																						28
2ØØ-2Ø9	3	8	5	1	1																					18
21Ø-219	4	1Ø	5																							19
22Ø-229	1	5	1																							7
23Ø-239	5	8	1																							14
24Ø-249	6	14	2																							22
25Ø-259	1	3	1																							5
26Ø-269	3	3	1																							7
27Ø-279	4	7	2																							13
28Ø-289	2	9	1		1	1		1	1																	16
29Ø-299	1Ø	3Ø	8	3	2		1	2	1		1															58
3ØØ-3Ø9	15	27	32	15	8	4	7	5	3	2	1	1														12Ø
31Ø-319	11	6Ø	87	69	78	51	31	6	7	3	2	1														4Ø6
32Ø-329	18	93	2Ø4	272	215	134	67	27	1		1	1	1													1Ø34
33Ø-339	2Ø	132	266	3Ø3	252	122	54	17	8	3	1															1178
34Ø-349	17	96	136	119	62	33	29	12	4				1													5Ø9
35Ø-359	12	93	123	68	26	13	9	5	3	1	2		1													356
	1919		1411		429		88		13		3			Ø		Ø		Ø		Ø		Ø		Ø		7632
	415		2214		865		226		35		9		5		Ø		Ø		Ø		Ø		Ø		Ø	

NUMBER OF RECORDS AT OR BELOW STALL SPEED (2.2 CM/SEC) 773

FREQUENCY DISTRIBUTION OF DIRECTION AND RATE

CRO Ø 36ØØØ4Ø477 GMT 6(T) 1672 CROZIER STRAIT 6 75288 97Ø29 6Ø 257 V6

DIR	2.3 TO 2.9	3 TO 6	6 TO 9	9 TO 12	12 TO 15	15 TO 18	18 TO 21	21 TO 24	24 TO 27	27 TO 3Ø	3Ø TO 33	33 TO 36	36 TO 39	39 TO 42	42 TO 45	45 TO 48	48 TO 51	51 TO 54	54 TO 57	57 TO 6Ø	6Ø TO 63	63 TO 66	66 TO 69	69 TO 72	72 TO 75	
CMS/SEC																										
Ø- 9	1	17	9	7	2																					36
1Ø- 19	2	8	1																							11
2Ø- 29	2	15	9	2	1																					29
3Ø- 39	2	1Ø	6	1																						19
4Ø- 49	5	8	5	1																						19
5Ø- 59		2	1																							3
6Ø- 69	2	3	1																							6
7Ø- 79		5	4	1																						1Ø
8Ø- 89	1	1	5	2																						9
9Ø- 99		3	2	3																						8
1ØØ-1Ø9		1	2	2																						5
11Ø-119		5	2	4																						11
12Ø-129	1	7	8	3	1																					2Ø
13Ø-139	3	5	13	7	5																					33
14Ø-149	1	14	25	26	14	5																				85
15Ø-159		14	41	43	46	28	14	3	1																	19Ø
16Ø-169		16	37	74	117	81	54	33	13	3																428
17Ø-179	2	8	29	46	67	49	31	13	9	5																259
18Ø-189	1	15	31	38	36	21	9	5	2																	158
19Ø-199		5	12	2	4		1																			24
2ØØ-2Ø9		3	12	4	1																					2Ø
21Ø-219		3	2	1																						6
22Ø-229		4	3	2																						9
23Ø-239		6	3																							9
24Ø-249		4																								4
25Ø-259		4	2	1																						7
26Ø-269		2	1																							3
27Ø-279		1	1																							2
28Ø-289		4																								4
29Ø-299		2	1																							3
3ØØ-3Ø9	1	1	2																							4
31Ø-319		1	6	1	2																					1Ø
32Ø-329	3	7	1Ø	11	11	5	1	1																		49
33Ø-339	3	15	18	22	2Ø	11	6	3	1																	99
34Ø-349		3	5	3	2	1																				14
35Ø-359	3	11	15	7	5	2																				43
		234		315		2Ø3		58		8		Ø		Ø		Ø		Ø		Ø		Ø		Ø		1652
	33		325		334		116		26		Ø		Ø		Ø		Ø		Ø		Ø		Ø		Ø	

NUMBER OF RECORDS AT OR BELOW STALL SPEED (2.2 CM/SEC) 2Ø

FREQUENCY DISTRIBUTION OF DIRECTION AND RATE

CRO271 4Ø17Ø3Ø477 GMT 6(B) 3Ø22 CROZIER STRAIT 6 75288 97Ø29 6Ø 459TC V6

CMS/SEC

DIR	2.3 TO 2.9	3 TO 6	6 TO 9	9 TO 12	12 TO 15	15 TO 18	18 TO 21	21 TO 24	24 TO 27	27 TO 3Ø	3Ø TO 33	33 TO 36	36 TO 39	39 TO 42	42 TO 45	45 TO 48	48 TO 51	51 TO 54	54 TO 57	57 TO 6Ø	6Ø TO 63	63 TO 66	66 TO 69	69 TO 72	72 TO 75	
Ø- 9	4	43	68	41	33	23	23	13	3	2																253
1Ø- 19	1Ø	43	39	15	4	2	3	4	3	1	2															126
2Ø- 29	11	52	17	6	1			1	1		1															9Ø
3Ø- 39	1Ø	65	22	2				2																		1Ø1
4Ø- 49	6	52	23	2						1																84
5Ø- 59	3	34	8																							45
6Ø- 69	3	26	13																							42
7Ø- 79	1Ø	23	17	1																						51
8Ø- 89	11	47	14	1																						73
9Ø- 99	12	46	17	1																						76
1ØØ-1Ø9	7	38	13	5																						63
11Ø-119	5	28	2Ø	6																						59
12Ø-129	3	16	26	1Ø	1																					56
13Ø-139		31	36	13	3	1																				84
14Ø-149	6	31	35	25	5	2	3	1																		1Ø8
15Ø-159	5	23	43	42	3Ø	11	5																			159
16Ø-169	3	32	44	38	26	8	1		1																	153
17Ø-179	4	8	22	9	8	4	1																			5Ø
18Ø-189	1	8	6		1																					16
19Ø-199	1	4	3		1																					9
2ØØ-2Ø9	4	3																								7
21Ø-219	3	5																								8
22Ø-229	1	2																								3
23Ø-239	2	4																								6
24Ø-249		1	1																							2
25Ø-259		4	1																							5
26Ø-269	1	3	1																							5
27Ø-279	3	3	3																							9
28Ø-289	1	1Ø	2	1																						14
29Ø-299	3	11	6																							2Ø
3ØØ-3Ø9	2	12	11	3					1	1																3Ø
31Ø-319		6	11	2																						19
32Ø-329	5	19	45	22	5	2	1	4	2																	1Ø5
33Ø-339	1	28	54	6Ø	25	18	7	5	1			1														2ØØ
34Ø-349	5	25	74	66	57	37	31	14	2																	311
35Ø-359	2	3Ø	1Ø1	1Ø5	113	68	38	16	6	3																482
	818		481		184		61		1		1		Ø		Ø		Ø		Ø		Ø		Ø		Ø	2968
	148	8Ø7		32Ø		115		21		3		Ø		Ø		Ø		Ø		Ø		Ø		Ø		

NUMBER OF RECORDS AT OR BELOW STALL SPEED (2.2 CM/SEC) 54

FREQUENCY DISTRIBUTION OF DIRECTION AND RATE

PUL Ø 4418210477 GMT 3(T) 1324 PULLEN STRAIT 3 75265 96059 6Ø 542 V6

CMS/SEC

DIR	2.3 TO 2.9	3 TO 6	6 TO 9	9 TO 12	12 TO 15	15 TO 18	18 TO 21	21 TO 24	24 TO 27	27 TO 3Ø	3Ø TO 33	33 TO 36	36 TO 39	39 TO 42	42 TO 45	45 TO 48	48 TO 51	51 TO 54	54 TO 57	57 TO 6Ø	6Ø TO 63	63 TO 66	66 TO 69	69 TO 72	72 TO 75	
Ø- 9		3		2																						5
1Ø- 19		1	1	1																						3
2Ø- 29	1	7	11	7	1																					27
3Ø- 39		9	29	23	17	1Ø	7	2																		97
4Ø- 49		1Ø	21	41	46	47	26	17	3																	211
5Ø- 59		15	16	18	13	4	1																			67
6Ø- 69		6	9	2	2																					19
7Ø- 79		3	5	3																						11
8Ø- 89		2	3																							5
9Ø- 99		1																								1
1ØØ-1Ø9		4	3																							7
11Ø-119	1	3	1																							5
12Ø-129		1																								1
13Ø-139		2																								2
14Ø-149	1	1																								2
15Ø-159	1	4	1																							6
16Ø-169	1	4																								5
17Ø-179	3	2	1																							6
18Ø-189	2	9	3																							14
19Ø-199		7	2		1																					1Ø
2ØØ-2Ø9		16	7	13	13	1																				5Ø
21Ø-219	4	11	18	32	26	19	9																			119
22Ø-229		22	21	25	46	31	16	1Ø																		171
23Ø-239	2	11	17	29	33	29	23	7	2																	153
24Ø-249		7	18	29	37	3	9																			1Ø3
25Ø-259	2	8	1Ø	32	13	2	1																			68
26Ø-269		3	9	15	7	1																				35
27Ø-279		8	12	8	2																					3Ø
28Ø-289		2	8	8	1																					19
29Ø-299		3	4	5																						12
3ØØ-3Ø9		5	1Ø	2																						17
31Ø-319		2	6	1																						9
32Ø-329		3	5	5																						13
33Ø-339		2	3																							5
34Ø-349		1																								1
35Ø-359	1	6	4	1																						12
	205		3Ø2		147		36		Ø		Ø		Ø		Ø		Ø		Ø		Ø		Ø		Ø	1322
	19	258		258		92		5		Ø		Ø		Ø		Ø		Ø		Ø		Ø		Ø		

NUMBER OF RECORDS AT OR BELOW STALL SPEED (2.2 CM/SEC) 2

FREQUENCY DISTRIBUTION OF DIRECTION AND RATE

PUL 25 400221Ø477 GMT 3(M) 134Ø PULLEN STRAIT 3 75265 96Ø59 6Ø 192TC V6

CMS/SEC

DIR	2.3 TO 2.9	3 TO 6	6 TO 9	9 TO 12	12 TO 15	15 TO 18	18 TO 21	21 TO 24	24 TO 27	27 TO 3Ø	3Ø TO 33	33 TO 36	36 TO 39	39 TO 42	42 TO 45	45 TO 48	48 TO 51	51 TO 54	54 TO 57	57 TO 6Ø	6Ø TO 63	63 TO 66	66 TO 69	69 TO 72	72 TO 75	
Ø- 9		5	4	2	1																					12
1Ø- 19		7	5	3	2	1																				18
2Ø- 29		8	6	1Ø	7	5	2	2																		4Ø
3Ø- 39	1	12	18	27	16	19	3Ø	32	22	27	8	9	5	2												228
4Ø- 49	1	7	11	11	14	15	14	21	11	8	11	7	6	2												139
5Ø- 59		6	2	13	6	5	3	2	3	2	1															43
6Ø- 69	1	1	2	4	4	1	1																			14
7Ø- 79		3	3	1	1																					8
8Ø- 89		1	1	2	1	1																				6
9Ø- 99			2																							2
1ØØ-1Ø9																										Ø
11Ø-119		1																								1
12Ø-129																										Ø
13Ø-139		2																								2
14Ø-149																										Ø
15Ø-159	1																									1
16Ø-169																										Ø
17Ø-179		2																								2
18Ø-189			1																							1
19Ø-199		3																								3
2ØØ-2Ø9		4	5																							9
21Ø-219		12	1																							13
22Ø-229	2	26	12	18	12	4	6	5	4	2																91
23Ø-239	1	2Ø	15	21	13	13	37	34	16	17	9	2														198
24Ø-249		1	1	7	14	29	25	27	2Ø	18	1Ø	6	2													16Ø
25Ø-259		2	3	2	14	18	13	13	11	8	1															85
26Ø-269		1	2	12	11	17	18	4	4																	69
27Ø-279		2	4	14	14	14	12	3																		63
28Ø-289			3	3	4	4	5																			19
29Ø-299			7	6	7	4	3																			27
3ØØ-3Ø9			4	3	8	5																				2Ø
31Ø-319		1	1	8	2	1																				13
32Ø-329			5	4	2	3																				14
33Ø-339		4	2	1	3	1																				11
34Ø-349		1	2	5	5																					13
35Ø-359		4	3	1	2	1																				11
	7	136	125	178	163	161	169	143	91	82	4Ø	24	13	4	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	Ø	1336

NUMBER OF RECORDS AT OR BELOW STALL SPEED (2.2 CM/SEC) 4

FREQUENCY DISTRIBUTION OF DIRECTION AND RATE

PUL 54 4816200477 GMT 3(B) 2717 PULLEN STRAIT 3 75265 96059 60 233TC V6

CMS/SEC

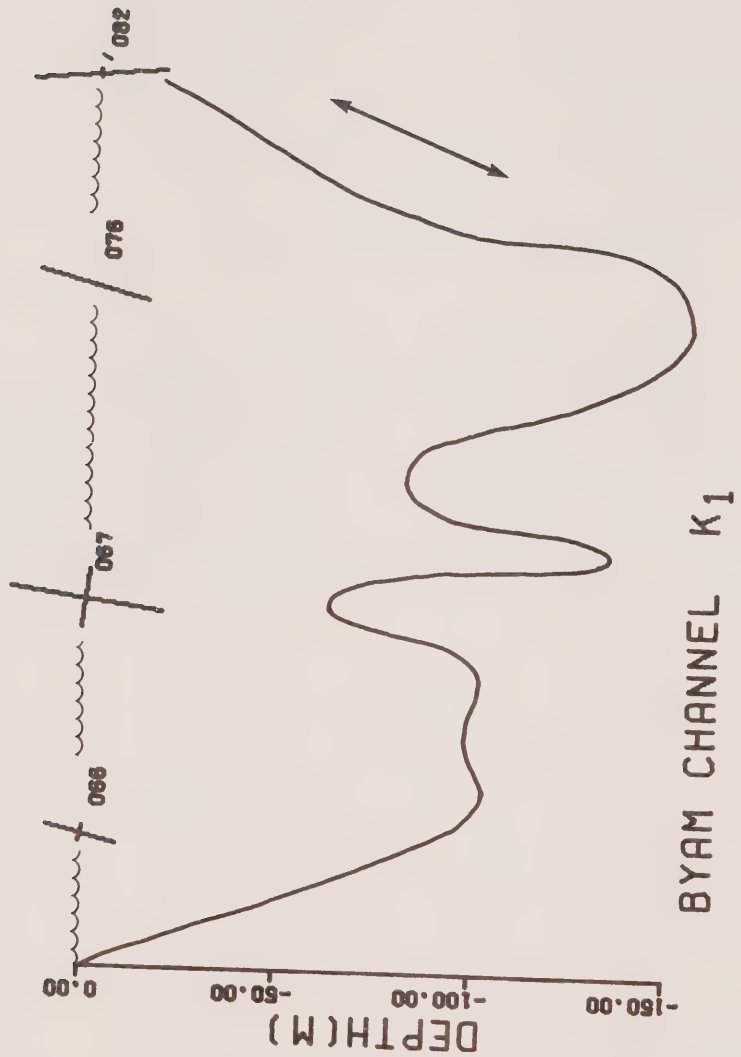
DIR	2.3 TO 2.9	3 TO 6	6 TO 9	9 TO 12	12 TO 15	15 TO 18	18 TO 21	21 TO 24	24 TO 27	27 TO 30	30 TO 33	33 TO 36	36 TO 39	39 TO 42	42 TO 45	45 TO 48	48 TO 51	51 TO 54	54 TO 57	57 TO 60	60 TO 63	63 TO 66	66 TO 69	69 TO 72	72 TO 75	
0- 9	1	4	3	13	4	5	4	5	2	5	2		1	5	2											56
10- 19		6	11	13	19	16	14	13	10	10	4	5	3	3												127
20- 29		6	8	14	19	28	36	33	25	17	3	6	3	4	2											204
30- 39	1	9	16	25	22	25	27	26	16	12	4	4	6	4	3	1										201
40- 49		11	13	9	6	9	3	4	5	9	6	6	2	3	3											89
50- 59		6	6	2	1	3	1	1	1	3	3	2	1			1										31
60- 69	2	7	8	3	2				4	3	3	1	1		1		1									36
70- 79		8	4	1	1							1														15
80- 89		4	7	4																						15
90- 99		2	6	2	1																					11
100-109	2	1	4																							7
110-119	1	3	2	1																						7
120-129	2	3		5	1																					11
130-139	1	3	2	3	1																					10
140-149		3	6	3	1																					13
150-159		2	9	8	2	1		1																		23
160-169		3	9	9	4	3	1	1																		30
170-179	1	2	11	3	8	8	2																			35
180-189		4	15	15	16	8			2																	60
190-199	1	6	8	14	16	3	5																			53
200-209	1	3	16	8	18	8	12		1		1															68
210-219		6	17	17	20	6	7	3	3																	79
220-229	1	5	12	26	29	21	6	7	1																	108
230-239		11	36	64	78	53	28	9	2	1																282
240-249		10	28	36	21	15	16	9	1	1																137
250-259		19	39	48	28	14	11	7	3																	169
260-269	1	9	24	30	33	7	6	1																		111
270-279		12	27	24	20	5		2																		90
280-289	1	2	36	24	7	3	1																			74
290-299		2	17	28	11		1																			59
300-309	1	6	26	20	28	10																				91
310-319		7	28	42	41	23	2	1																		144
320-329	1	7	17	21	21	27	1	2	1																	98
330-339		5	8	12	12		2	1					2													42
340-349	1	7	10	7	10	7	1		3		2		1	1	1											51
350-359		5	9	21	8	7	2	3	2	1	4	1	1	1												65
	209		576		315		129		62		26		21		2		Ø		Ø		Ø		Ø			2703
	19	498		509		189		82		32		21		12		1		Ø		Ø		Ø		Ø		

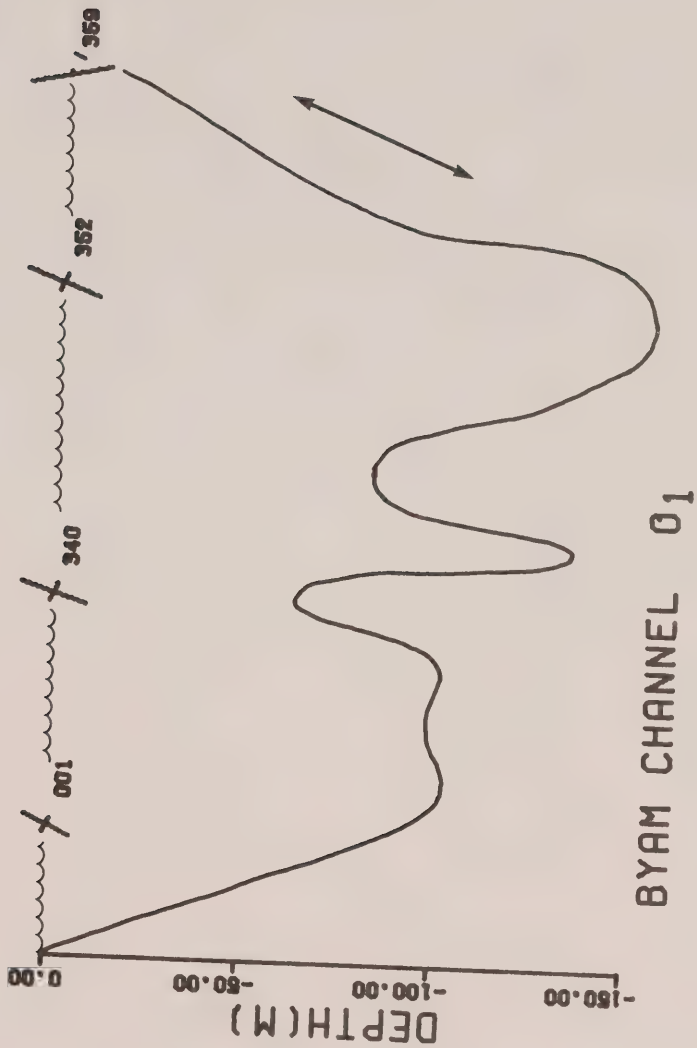
NUMBER OF RECORDS AT OR BELOW STALL SPEED (2.2 CM/SEC) 14

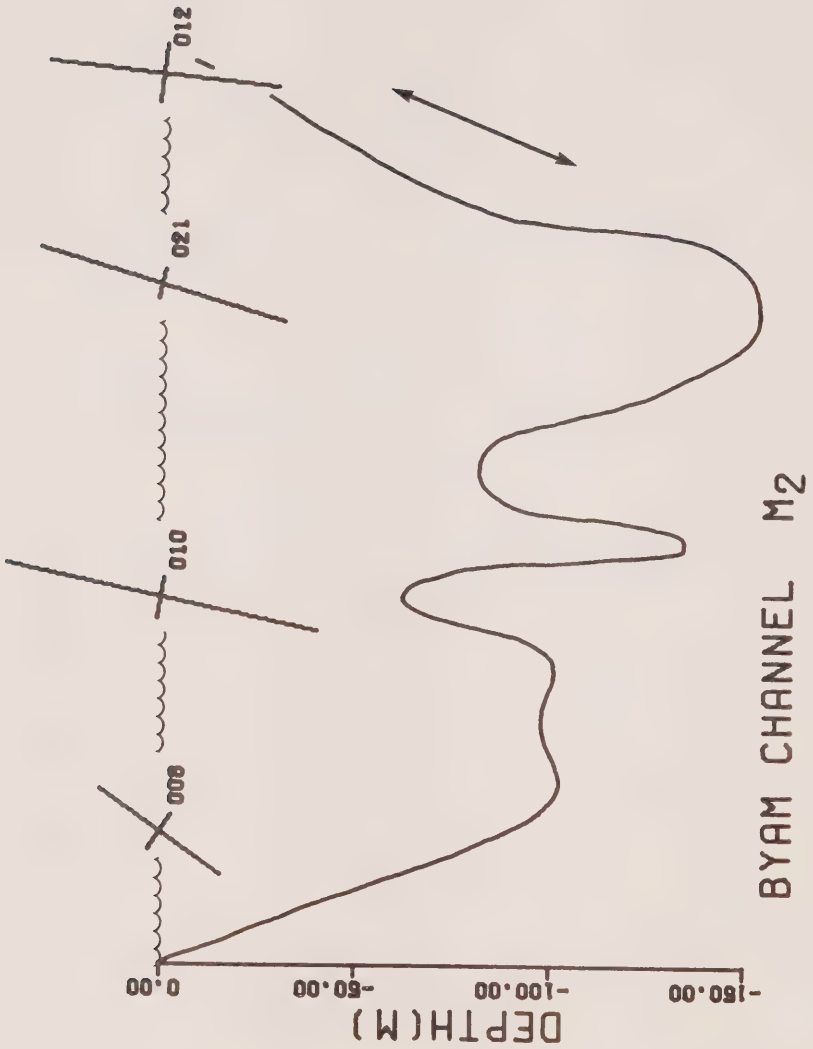
APPENDIX B

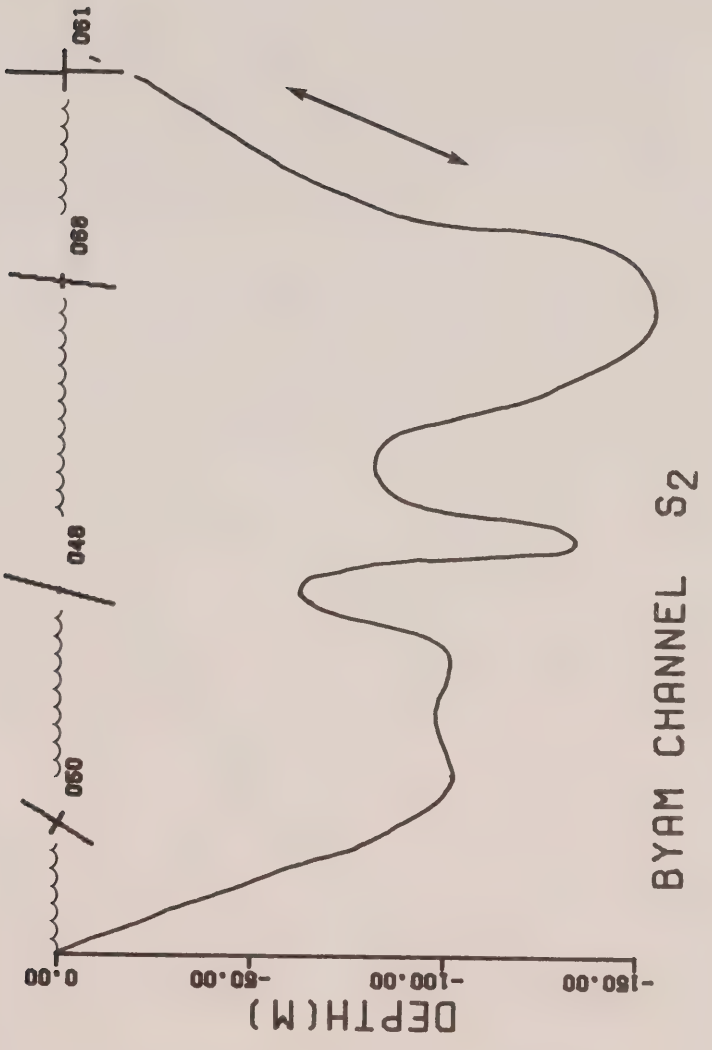
TIDAL ELLIPSES

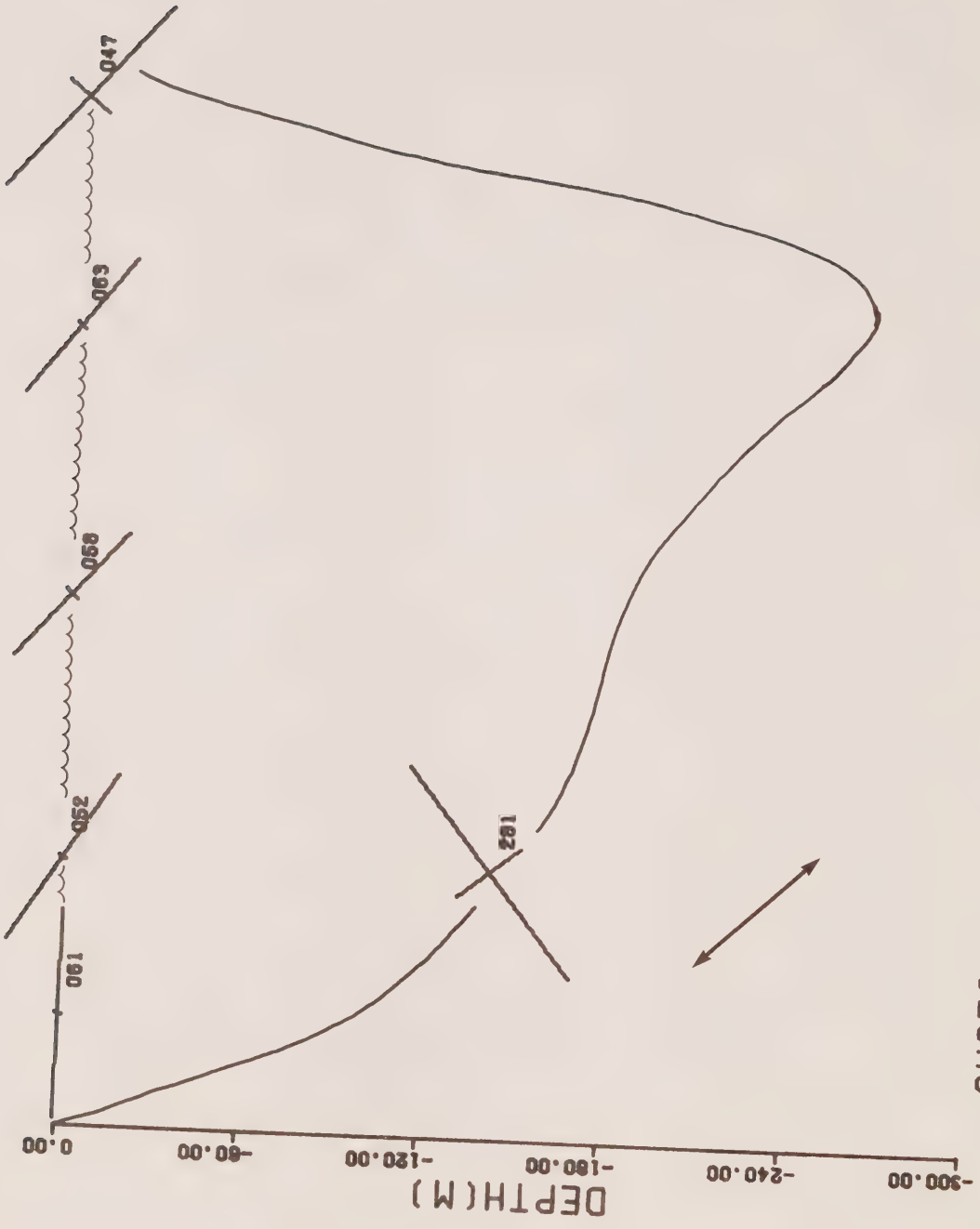
In the following, each channel is portrayed in four cross sections, one for each of the major tidal constituents. The major and minor axes of the ellipses are shown located at the appropriate current meter positions. The lengths of the axes are proportional to the current speed with 1 cm representing 4 cm s^{-1} . North is towards the top of the page and the orientation of the channels relative to north-south is indicated by the double-headed arrows. The major axes of the ellipses usually lie along or close to the channel orientation. The numbers beside each set of ellipse axes is G, the Greenwich phase.


082
076
067
066
0.00
-50.00
-100.00
-150.00
DEPTH(M)
BYAM CHANNEL K1

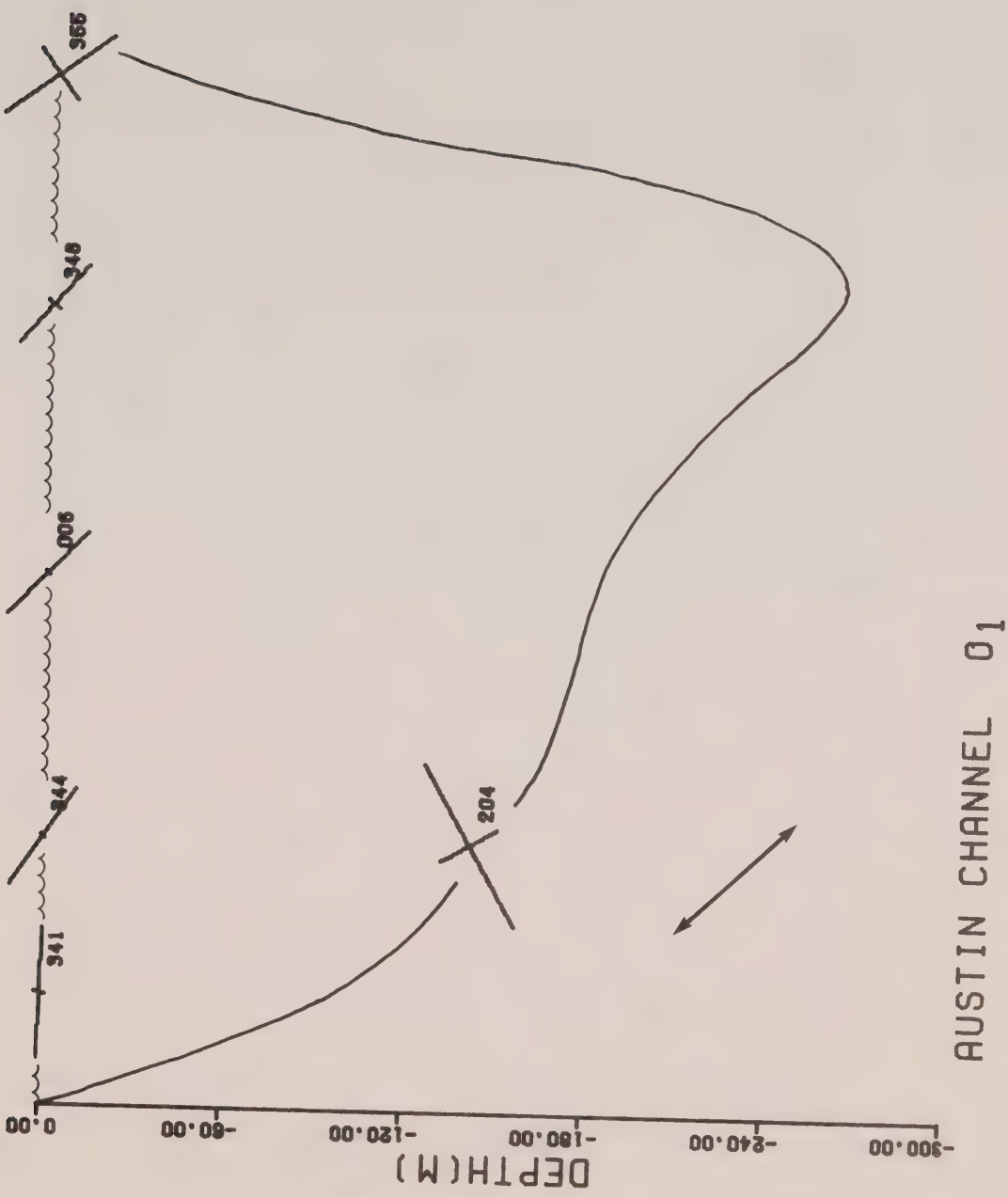

001
340
362
368
0.00
-50.00
-100.00
-150.00
DEPTH(M)
BYAM CHANNEL O_1


BYAM CHANNEL M2
DEPTH(M)
0.00
-50.00
-100.00
-150.00
008
010
120
210

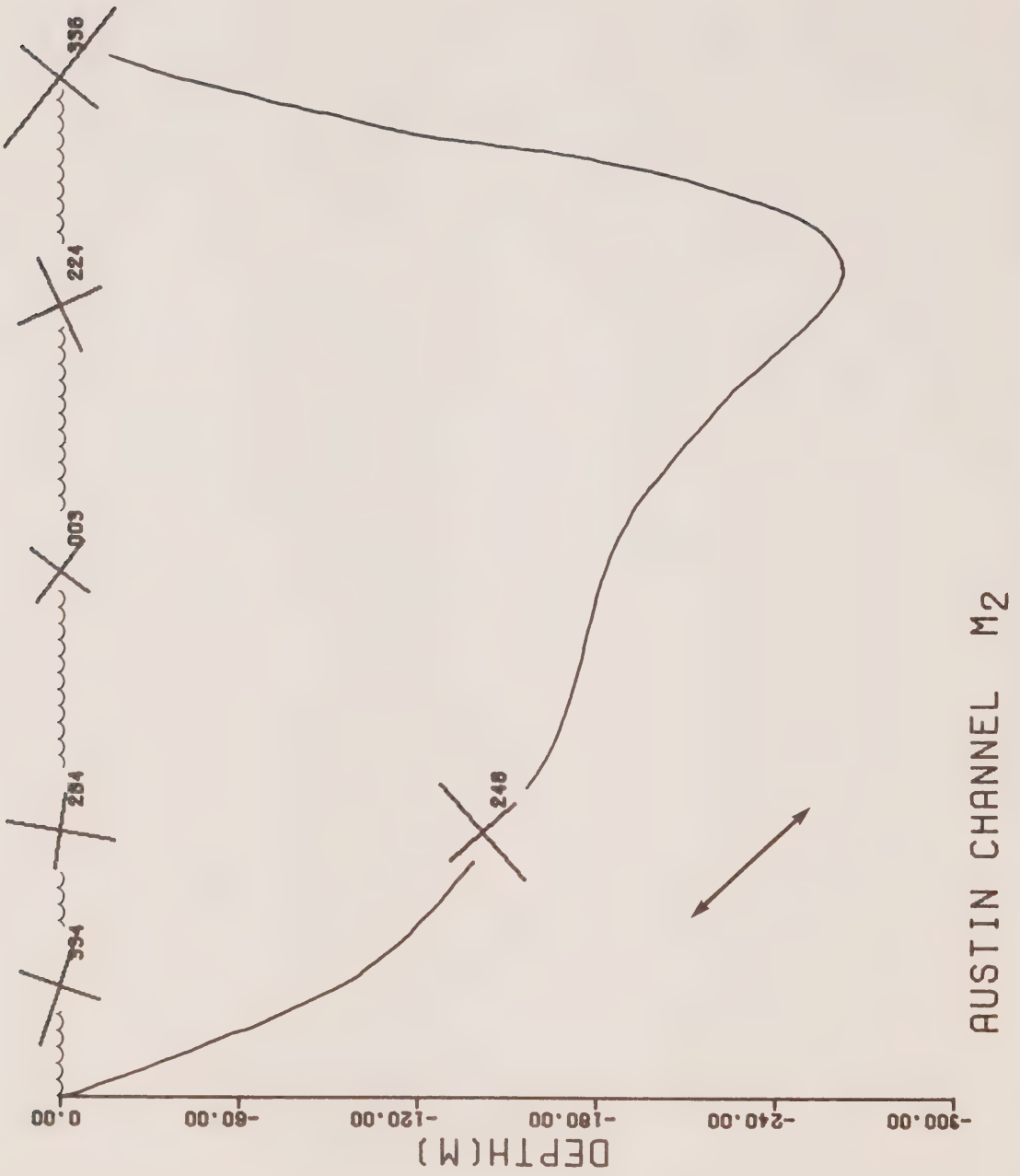

060
048
068
061
0.00
-50.00
-100.00
-150.00
DEPTH(M)
BYAM CHANNEL S2

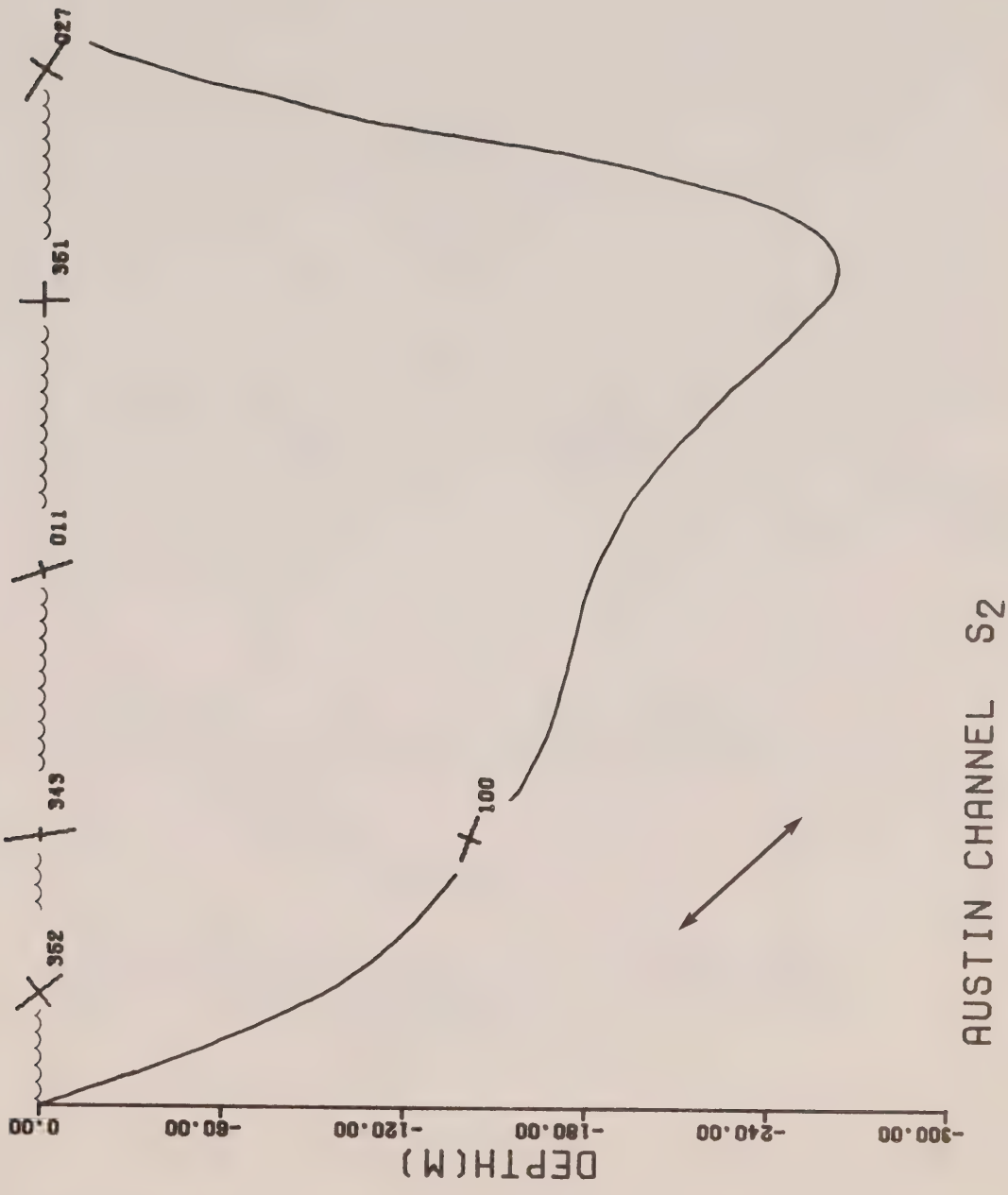


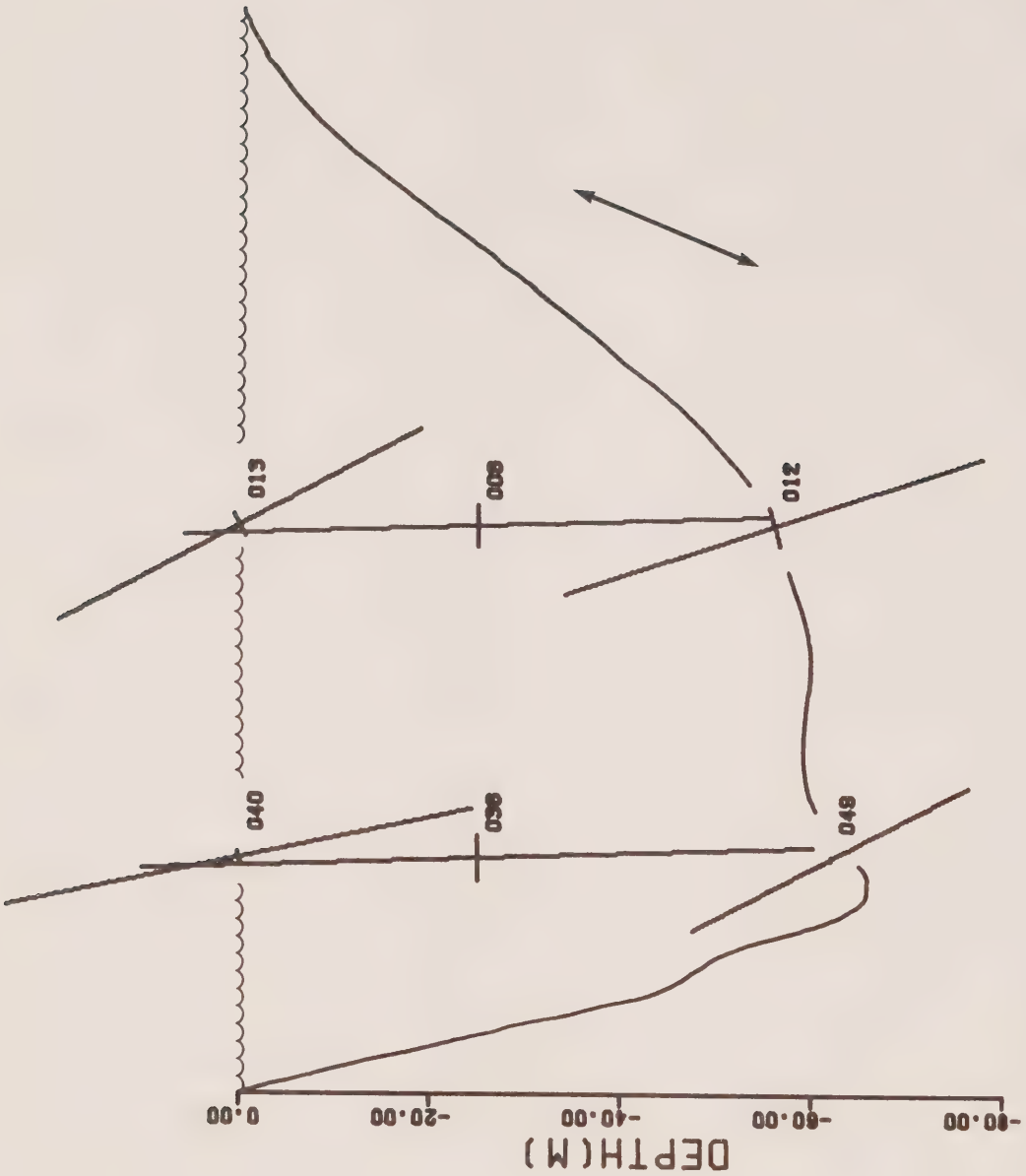
AUSTIN CHANNEL K_1



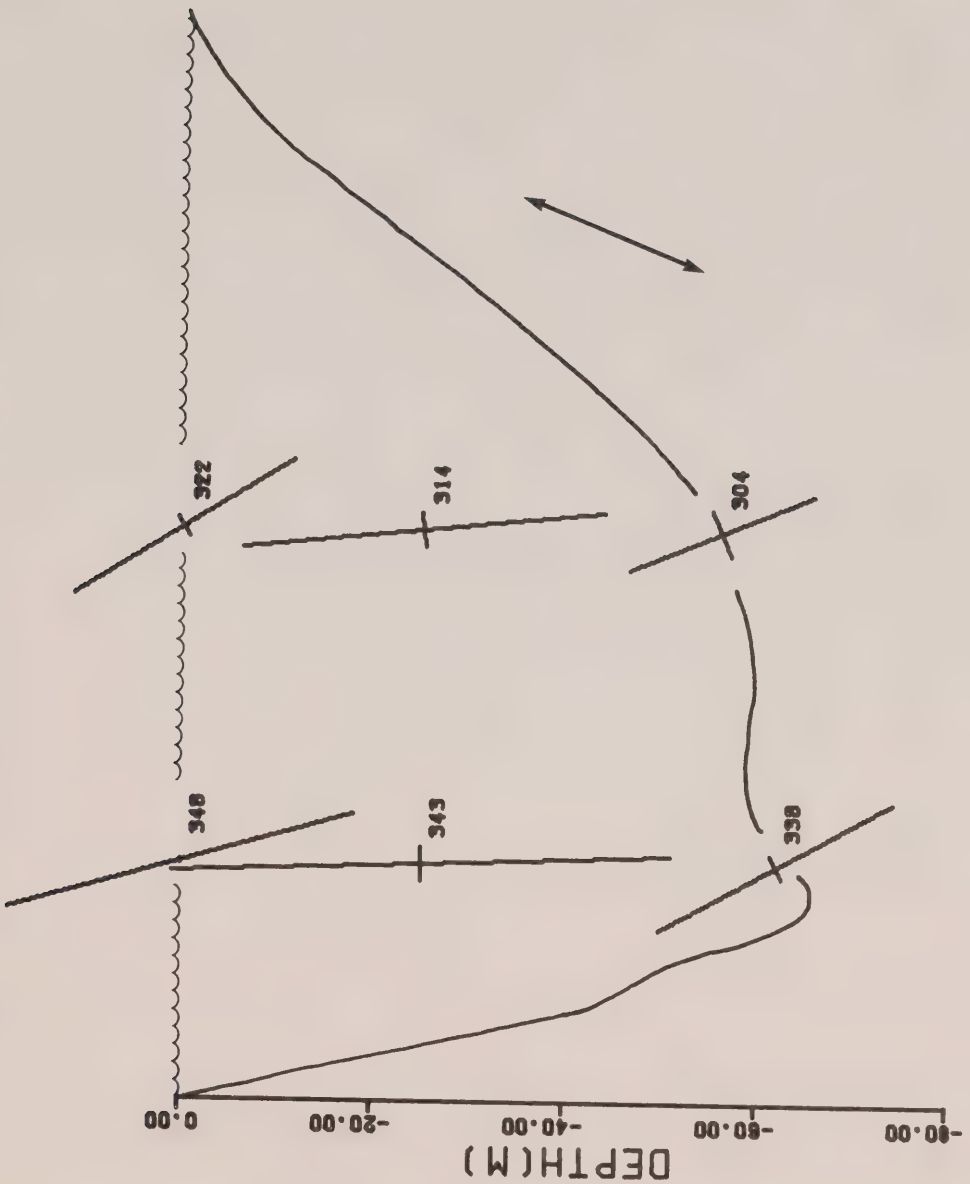
AUSTIN CHANNEL O_1


AUSTIN CHANNEL M2
DEPTH(M)
0.00
-60.00
-120.00
-180.00
-240.00
-300.00
336
224
003
284
354
248

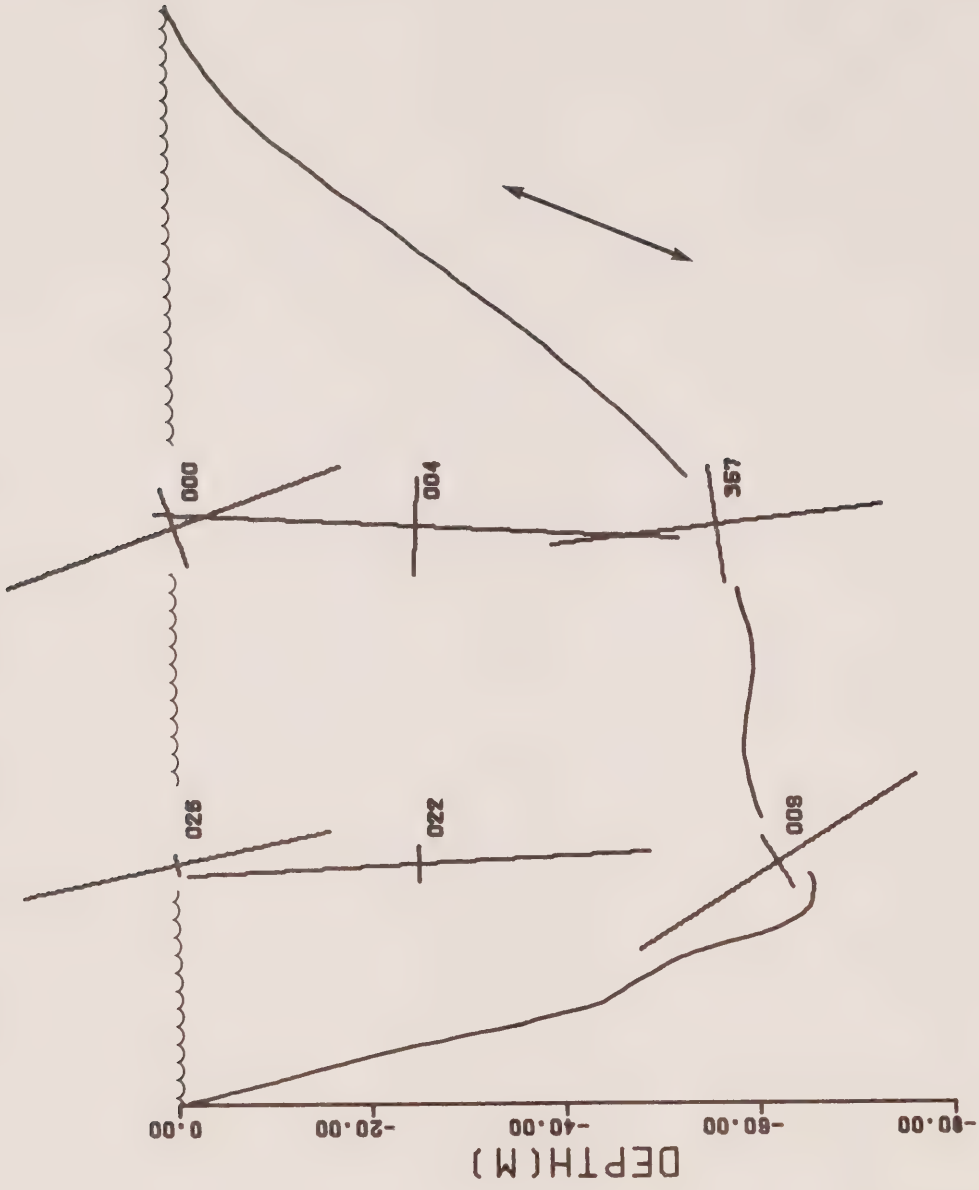

AUSTIN CHANNEL S2
DEPTH(M)
0.00
-60.00
-120.00
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343
011
361
027
100



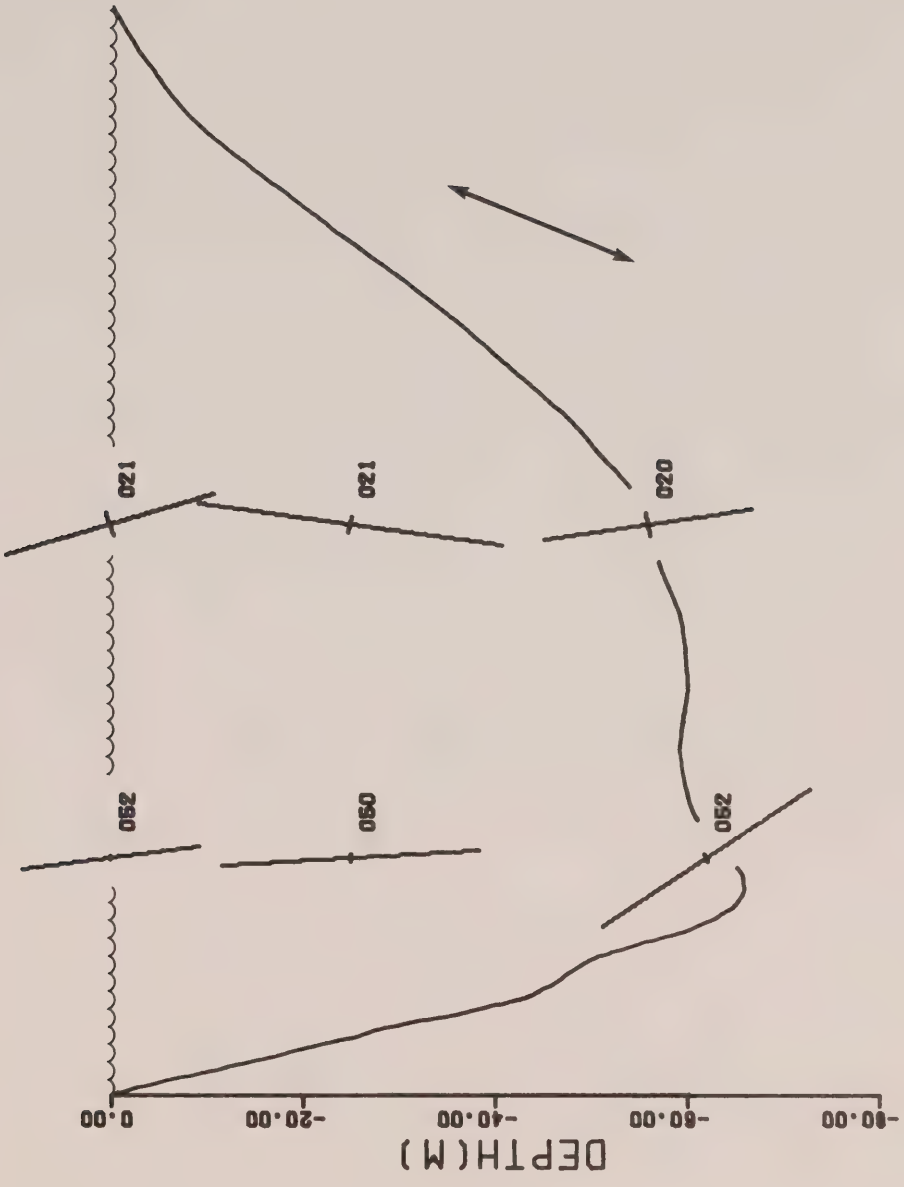
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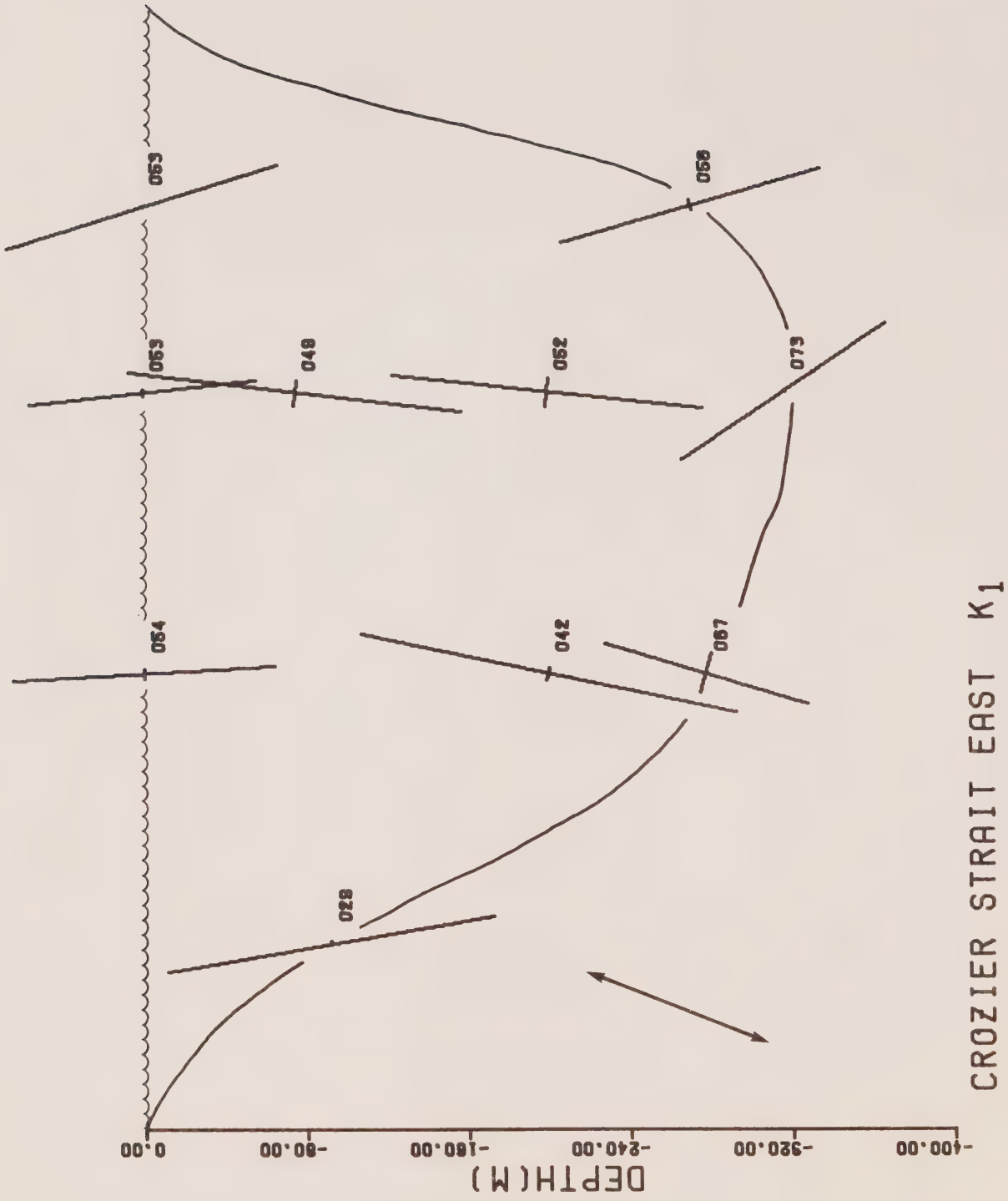
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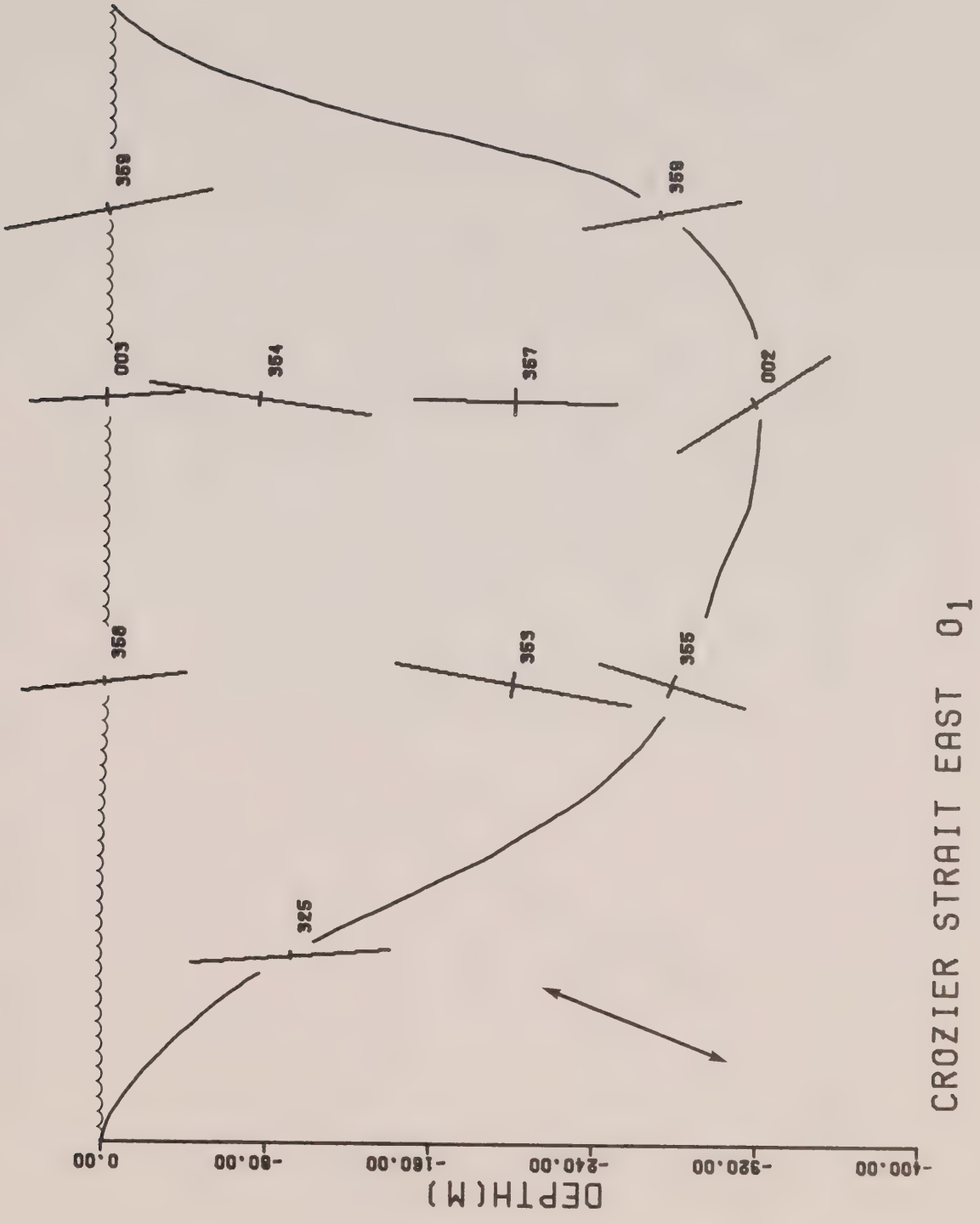


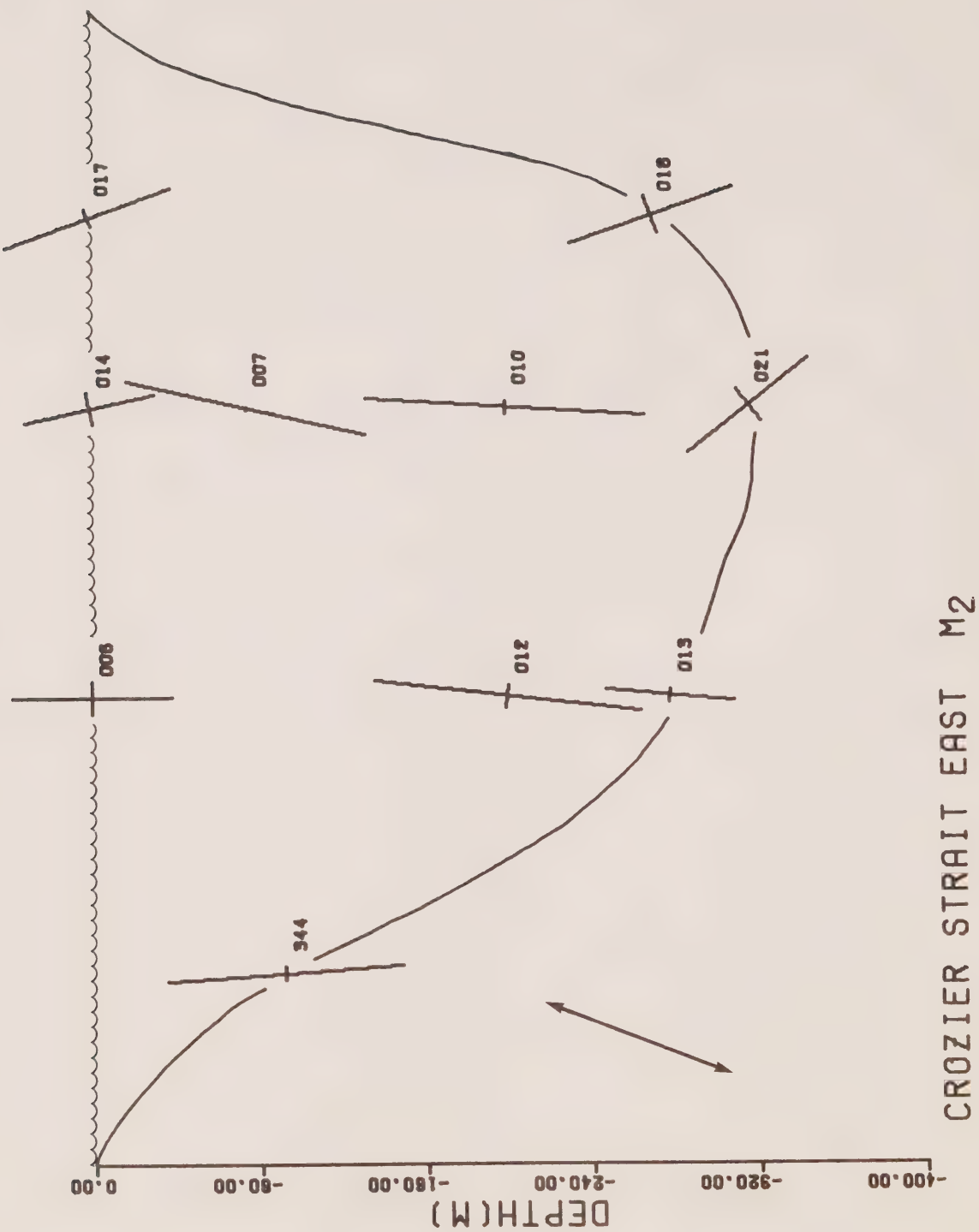
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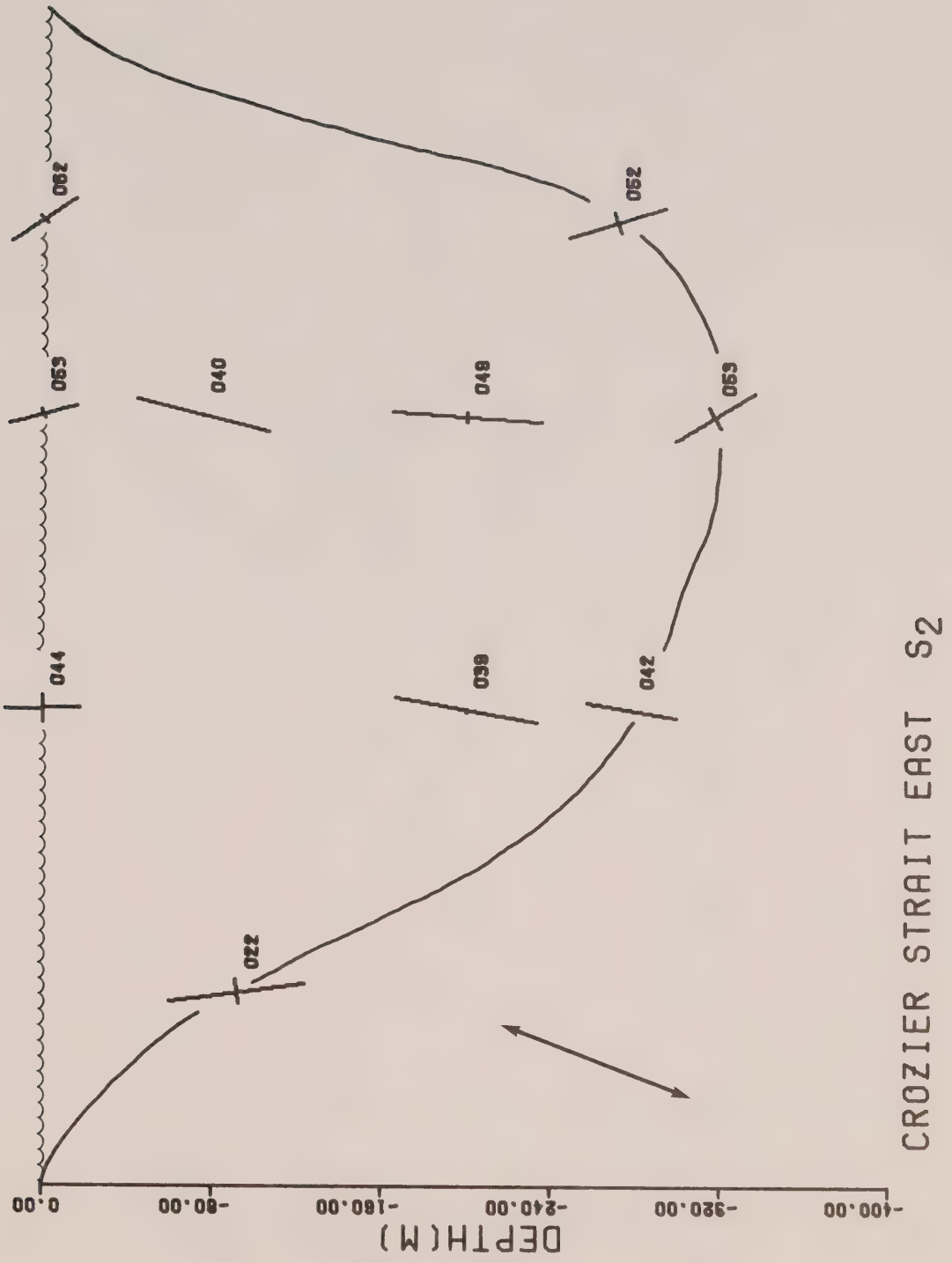


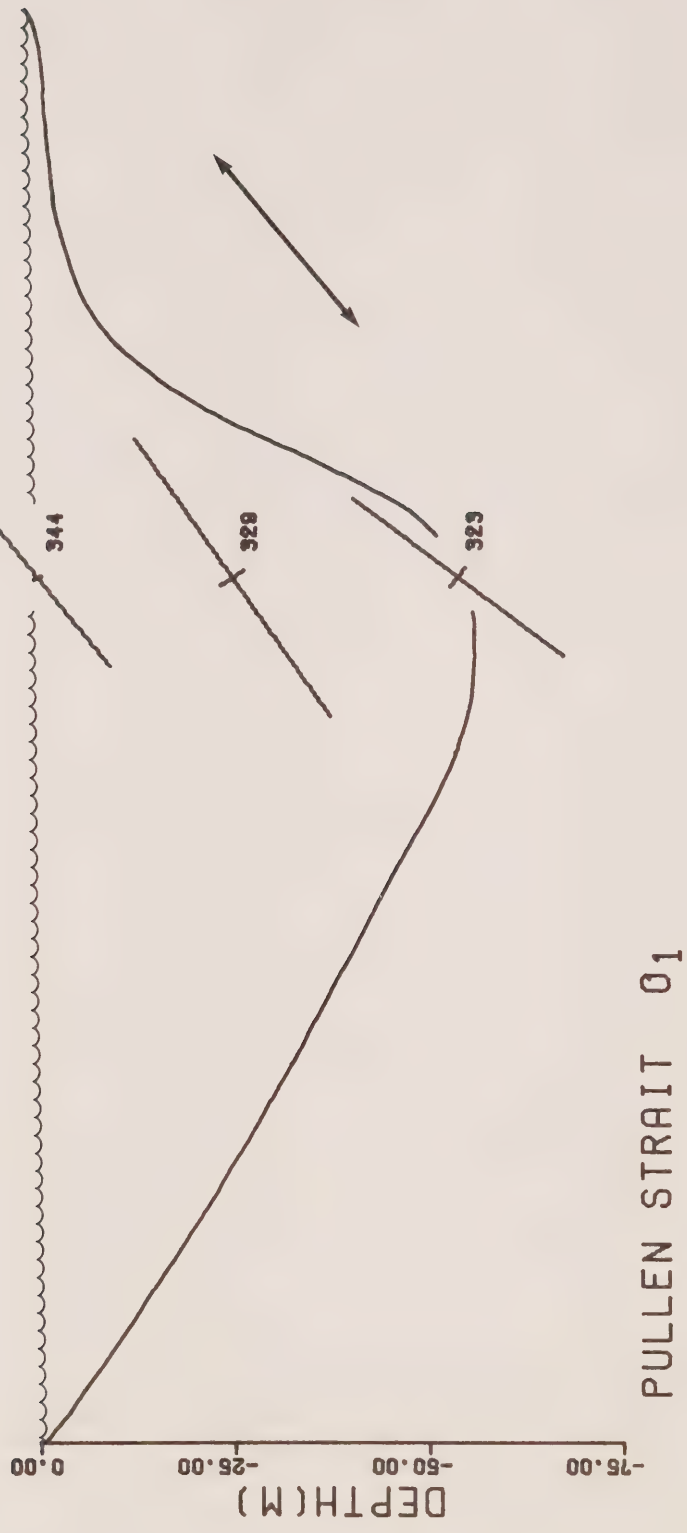
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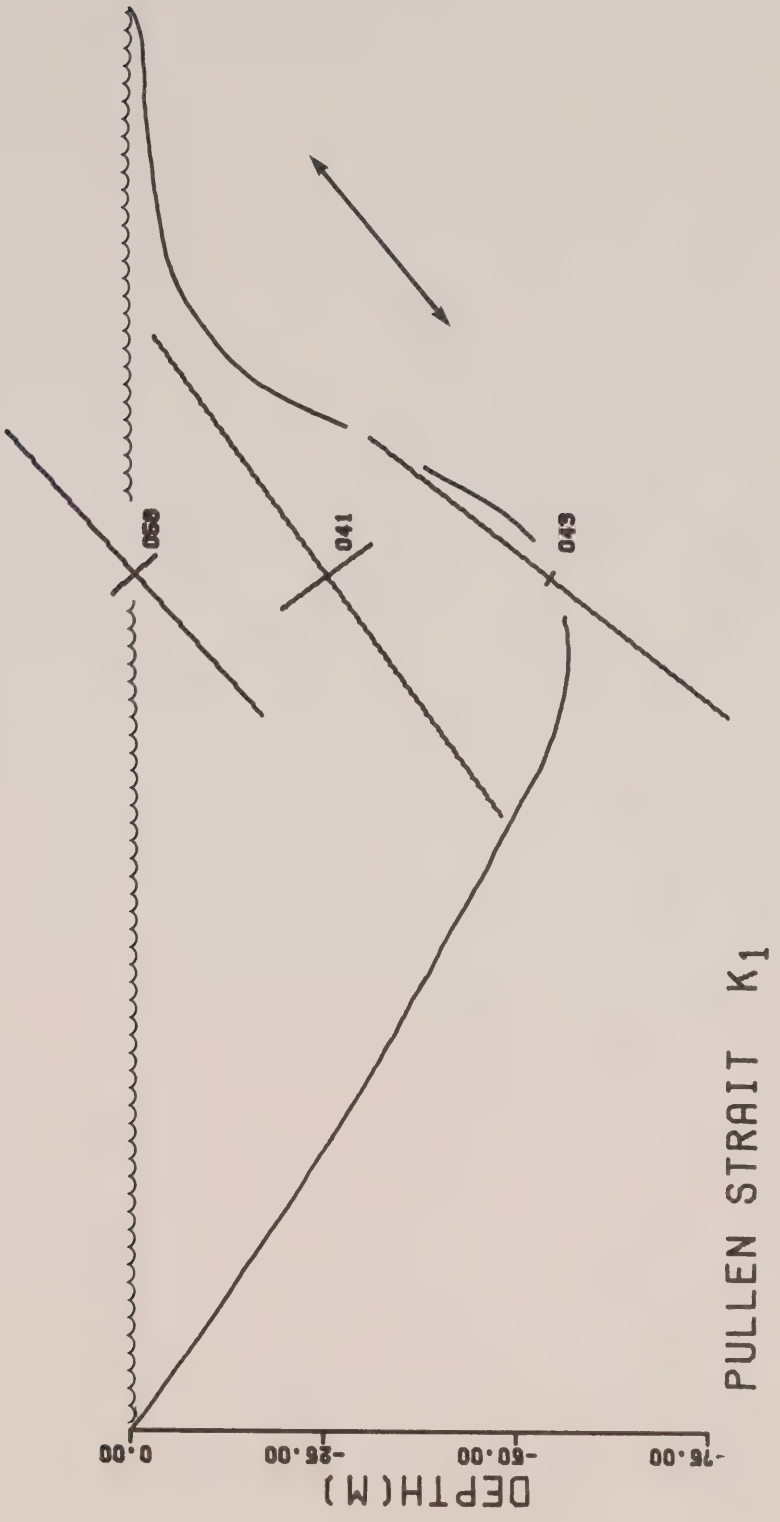

CROZIER STRAIT EAST K1
DEPTH(M)
0.00
-80.00
-160.00
-240.00
-320.00
-400.00
063
053
048
052
058
073
064
042
067
028

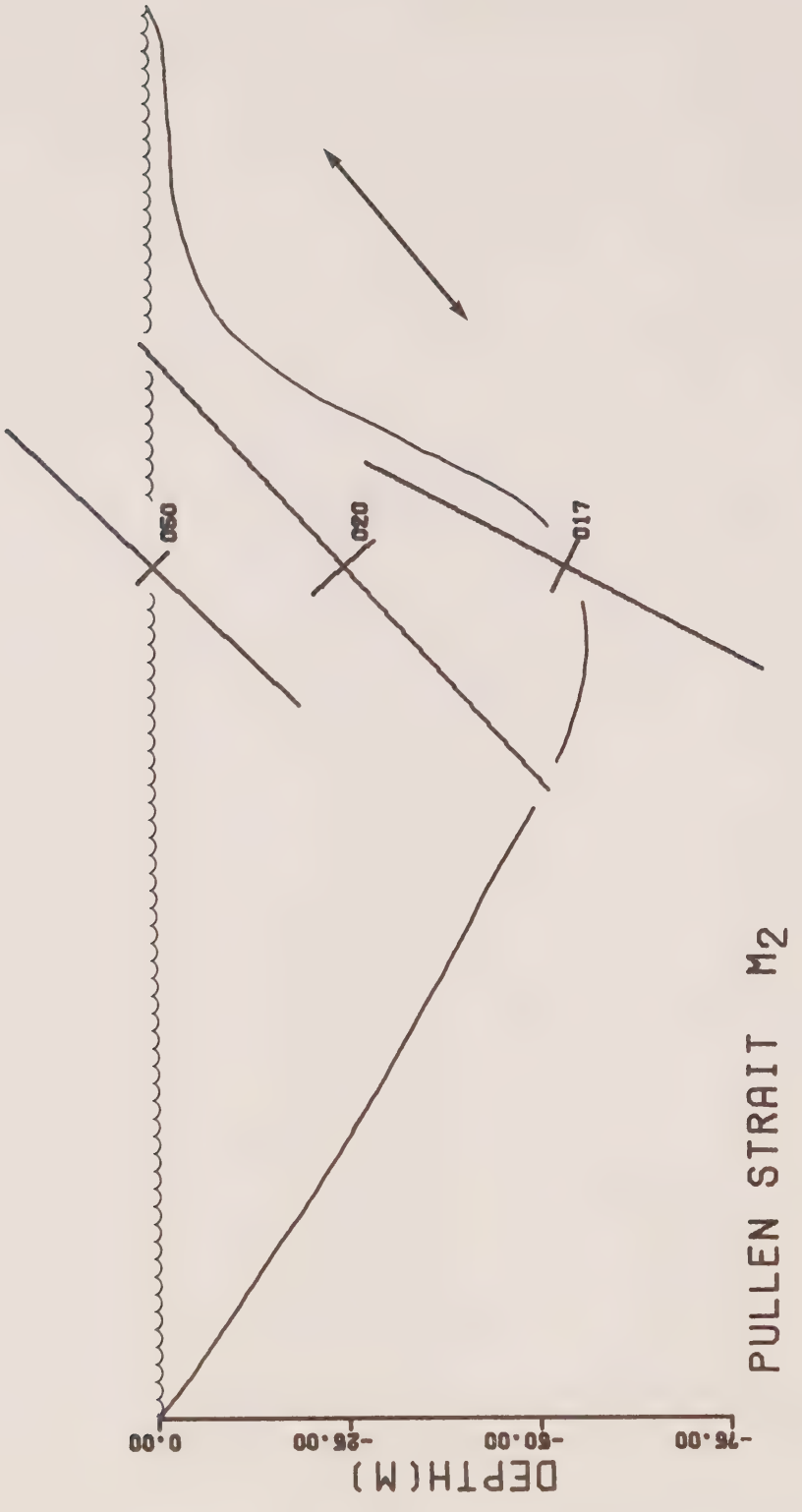

CROZIER STRAIT EAST O_1
DEPTH(M)
0.00
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-160.00
-240.00
-320.00
-400.00
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353
355
357
358
002

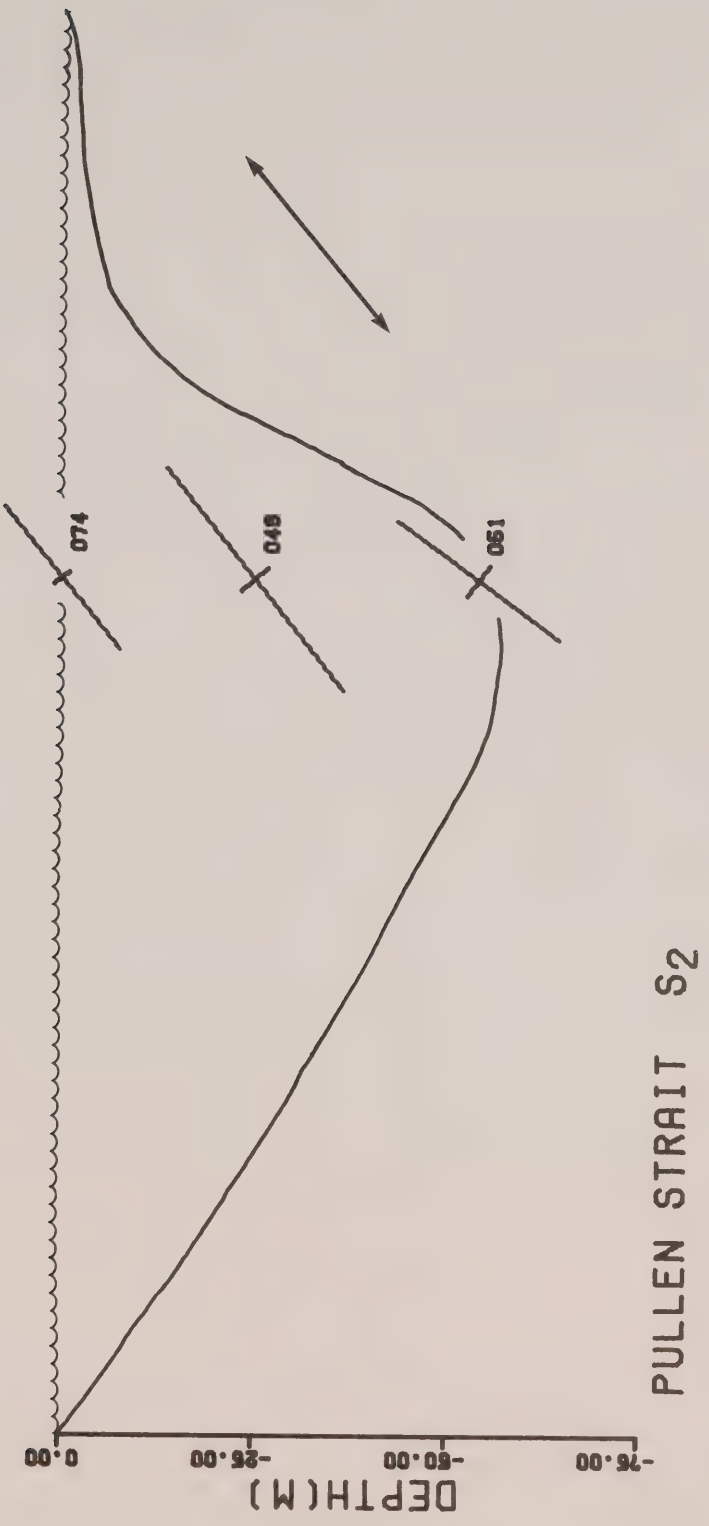

CROZIER STRAIT EAST M2
DEPTH(M)
0.00
-80.00
-160.00
-240.00
-320.00
-400.00
006
014
007
017
010
018
021
012
013
344


CROZIER STRAIT EAST S2
DEPTH(M)
0.00
-80.00
-160.00
-240.00
-320.00
-400.00
022
044
038
042
040
048
052
053
062


344
328
323
0.00
-25.00
-50.00
-75.00
DEPTH(M)
PULLEN STRAIT O1


PULLEN STRAIT K1
DEPTH(M)
0.00
-25.00
-50.00
-75.00
050
041
043


PULLEN STRAIT M2
DEPTH(M)
0.00
-25.00
-50.00
-75.00
050
020
017


074
048
051
0.00
-25.00
-50.00
-75.00
DEPTH(M)
PULLEN STRAIT S2

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ABSTRACT

Ocean Chemistry carried out sampling and analysis from the C.S.S. Parizeau from February 4-16, 1977. Data were obtained for salinity, temperature and nutrients (reactive silicate, nitrate and phosphate) and the results are reported here. The distribution of these water properties is interpreted in the light of the circulation occurring in Kitimat Arm and recommendations for chemical sampling are given. At one station an intercomparison of filtered and non-filtered nutrient samples was made. The results of analysis of variance show that while silicate and phosphate are unaffected by filtering, in non-turbid water, the nitrate levels are increased slightly (but statistically significantly). Lead-210 geochronology was carried out on one box core, and the apparent uniform sedimentation rate is about 0.47 cm y^{-1}. There was evidence, however, of turbidity flows which may increase the overall sedimentation rate. Sampling was also carried out for hydrocarbons in the water column, sediments, intertidal organisms and the plankton, and some sediment samples were obtained at Porpoise Harbour, the site of a recent PCB spill. The results of analysis on these materials are not reported here.

ACKNOWLEDGEMENTS

We would like to thank all of the people who helped in producing this report. B. Mathias prepared the manuscript and Chart Production provided the photographic reductions. Figures where drawn by L. Barry and A. Chesshire. Identification of the biological material from the net hauls was done under contract by G. Silver. L. Forcier developed and ran the ANOVA programs for the determination of the effect of filtering on nutrients. W. H. Bell and L. S. C. Thomson reviewed the rough draft. We also thank the ship's personnel on the C.S.S. Parizeau for their friendly and cooperative assistance throughout the sampling programme.

INTRODUCTION

From February 4-16, 1977 Ocean Chemistry conducted a cruise to Kitimat Arm, a fjord located on the mainland coast of British Columbia at a latitude of about 53°N. At that time Kitimat was being considered as the location of an oil pipeline terminal, and in the event that a full scale survey would be required at a later date we conducted this cruise as an exploratory operation. Sampling was carried out for salinity, temperatures and nutrients (reactive silicate, phosphate and nitrate). In order to obtain baseline information on hydrocarbons, samples of the plankton were obtained by net hauls, bottom grabs were taken, mussels were collected at several beaches, and sea water was obtained for hydrocarbon analysis.

Because there had been a recent spill of polychlorinated biphenyls (PCBs) at Porpoise Harbour, which is located on the mainland coast of B. C. near Prince Rupert at a latitude of about 54°N, we also examined that area, taking a series of bottom grabs from the harbour entrance up to the spill area. We attempted to box core at the spill site, but fast currents and bottom debris prevented us from successfully doing so.

The detailed survey is now being undertaken and some of the samples obtained during this cruise (for hydrocarbon analysis) will be analyzed as part of this programme. This data report is intended to make the information obtained during the cruise, accessible.

SAMPLING

a) Net Hauls

Miller net hauls were run at approximately 5 knots for about a half hour. Since only small amounts of material were obtained, the samples from four Miller nets (#6 mesh) were pooled. Material was preserved for biological identification by storing it in buffered 5% formaldehyde solution. After the cruise, the samples were transferred to 95% ethanol through a series of increased concentrations and then shelved for about two weeks before analysis.

Neuston net hauls were also conducted at 5 knots for a half hour period. Only one tow contained tar balls and plastic material. Samples were preserved for biological identification as described above.

b) Water Sampling

Hydrocasts were carried out with 1.7 L Niskin P.V.C. bottles at standard depths (H.O. Publication #607, 1978). Samples were drawn for oxygen analysis, salinity and nutrients. Each bottle was equipped with two reversing protected thermometers, and all bottles at depths greater than or equal to 200 m had one unprotected thermometer. In all cases the depth calculated from the unprotected thermometer was within 3 m of the depth recorded on the meter

block at the time of sampling.

Oxygen samples were drawn off first into calibrated 125 mL stoppered flasks which were immediately "pickled" with manganous chloride/alkali iodide solution in accordance with the method outlined in the Reference Manual for Ocean Chemistry Division Sampling Techniques (1976). Analysis was carried out within one day. Salinity samples were stored on deck in tightly stoppered salinity bottles with analysis being carried out after returning to the laboratory. Nutrients were sampled in duplicate (2 glass, 2 plastic) 20 mL screw cap test tubes.

These were filled about 3/4 full and frozen in the upright position immediately. At Station 8 samples for nutrients were drawn in triplicate both filtered and unfiltered to examine the influence of filtering on nutrient concentrations.

Sea water was obtained for hydrocarbon analysis by using the Clark-Blumer sampler (Clark et al, 1967) equipped with a rupture disc for the deep casts, and with an air activated valve for the shallow casts. Silk gloves were used to handle the 5 L glass inserts and during rupture disc installation. Each sample was immediately poisoned with $HgCl_2$ and stored in a cooler at 4^oC but but frozen.

c) Sediment Sampling

Surface sediment was obtained where possible (soft bottom) with a Ponar grab sampler. Subsamples for hydrocarbon or PCB analysis were placed in a cleaned aluminum can, and the lids were wrapped with Teflon tape. The samples were then frozen and are stored frozen. Subsamples for mercury analysis were placed in Whirl-Pak bags and were immediately frozen.

Box coring was carried out with the Soutar-Bruland clear vented slow entry box coring device. Samples were obtained by inserting cut off plastic syringes through the specially machined holes on the side of the box corer. The sediment was extruded from the syringe with the exception of the last ½" of material which had been next to the wall and was likely disturbed during coring. Sediment was stored in plastic Whirl-Pak bags with a minimum of air space and was subsequently frozen. These samples were later subjected to ^{210}Pb, and organic carbon analysis.

ANALYTICAL METHODS

Oxygen was determined by the Micro-Winkler technique (Carpenter, 1965) in accordance with the procedure outlined in the Ocean Chemistry Division reference manual. The percent saturation was calculated by using the formula given by Weiss (1970) for oxygen solubility as a function of temperature and salinity.

Salinities were analyzed after the cruise with an Autolab inductive salinometer with duplicate determinations being within $\pm$ 0.003°/oo.

Analysis for reactive silicate, nitrate and phosphate was carried out on a Technicon II auto-analyzer using the methods outlined in the Reference Manual for Ocean Chemistry Division Sampling Techniques (1976). The basis of the technique for silicate involves reaction in acid medium with ammonium molybdate to form β-molybdosilicic acid which is subsequently reduced by ascorbic acid to form the characteristic molybdenum blue colour. Oxalic acid is used to prevent interference from phosphate. Nitrate is analyzed by reduction to nitrite in a copper-cadmium reductor column. The nitrite reacts with sulfanilamide in acid to form a diazo compound which on coupling with N-1-napthlethylenediamine dihydrochloride forms a red azo dye. Ortho phosphate is determined by forming molybdophosphoric acid which is reduced by ascorbic acid to give the molybdenum blue colour. In all three cases absorbance of the coloured complex is measured.

Lead-210 was measured by the method described in Matsumoto (1975). Sediment samples were thawed and dried at 110°C to determine moisture content. The residue was pulverized, leached with concentrated nitric acid, and the solid phase was filtered off. The lead was purified by electrodeposition on a platinum anode as PbO_2. The sulphate powder was dried and allowed to sit for at least 30 days to allow growth of the daughter ^{210}Bi to approach steady state. The radioactivity was measured by counting the β decay of the ^{210}Bi daughter.

Organic carbon was determined by the method of Gaudette et al (1974). Essentially the sediment was subjected to oxidation by an excess of $K_2Cr_2O_7$ solution in sulfuric acid for thirty minutes. After oxidation the solution was back titrated with ferrous ammonium solution.

Density of the solid material was determined by pycnometry, and salt corrections were applied by assuming that the salinity of the pore water was the same as that of the overlying water.

The preserved biological samples were split to 1/8th fractions and grouped according to phylum. Crustacea were separated by class and sometimes order. Sample MNT-1 was split into ¼ fractions and copepods were split to 1/16th fractions. A count was made of each group in the splits and each specimen was identified as far as possible. Each count was multiplied to "numbers in whole sample" and the percent of sample for each was computed.

The precision and accuracies of the various analyses used here are reported in Table 1. The 95% confidence, or 2 σ limits are given.

DISCUSSION

a) Water Properties

Previous cruises have been made to the Kitimat area and are reported on by Pickard (1961), and Waldichuk et al (1968). It would be premature to base too many conclusions on data obtained during this single cruise, however some interesting trends were observed with implications on conducting a baseline study for hydrocarbons.

The cruise was run in February, and since the main contributor to fresh water runoff in this mainland fjord is glacier and snow melt water, river input was at a seasonal low (Pickard, 1961). Furthermore this year was unusual in that a very low snowfall was evident. All beaches were clear of snow, as were the hills surrounding the channels investigated. The locations of the stations occupied during this cruise are shown in Figures 1 and 2 and are given in Table 2.

Pickard (1961) has classified Douglas Channel as belonging to group A.1 inlets; that is having low surface salinities at the head (0.1-2°/oo) and about 5-20°/oo surface salinity at the mouth. More explicitly the A.1 inlets are those with a relatively high runoff. Kitimat Arm can effectively be seen as a two layer system with a shallow pycnocline at the head gradually deepening from less than 10 m to about 50 m at the mouth (Figures 3 and 4). More uniform mixing down to 100 m on the shelf outside the sill is evident at Station 1. Temperature contours shown in Figure 5 follow a similar trend with uniform 8°C water extending down to 100 m at Station 1, and a cold surface layer associated with the low salinity runoff. The cold surface layer deepens towards the mouth as expected. Both subsurface temperature minimums and maximums have been observed in many of the mainland inlets (Pickard, 1961). The data here show a subsurface maximum which can be seen quite clearly on Figure 5 when at Stations 7 to 11 the water from 100-150 m exceeds 8°C in temperature. Only across the sill on the shelf are similar levels occurring. In conjunction with the temperature maximum, an oxygen maximum is also present (Figures 7 and 8). Oxygen levels also tend to be highest in the surface where both low temperature and low salinity lead to high gas solubility. At Stations 1 and 2 high dissolved oxygen levels (near saturation) extend down to 100 m. Inside the sill and deeper than it, the oxygen levels decrease with depth, but in no case do they approach anoxic conditions with the lowest levels being about 3.3 mL L^{-1}. It has been observed that significant seasonal variation of the deep water (that below the sill level) does not take place although apparently periods of deep water exchange take place due to inflow of deep water at irregular intervals. This must occur frequently enough to prevent anoxic conditions from taking place on a regular basis.

The distribution of nutrients (reactive silicate, phosphate and nitrate) are shown in Figures 9, 10 and 11. All three tend to increase with depth with the highest levels being found inside the sill below the depth of the sill. If the nutrients are plotted against salinity (Figures 12, 13 and 14) some deductions can be made about the water circulation. The silicate levels in Figure 12 appear to be more or less constant at the surface at about 30-37 µg at L^{-1} and salinities of 29-32°/oo. Above a salinity of 31°/oo two branches are seen. The high silicate branch includes all points below the sill where high salinity occurs. The low silicate branch includes at its extremity all points from outside the sill (Stations 1 and 2). The points between the low silicate extremity and the main cluster come from intermediate depths (75-200 m) at stations inside the sill, particularly from stations closer to the mouth such as 3, 4 and 6. The indication is that while some of the water inside the sill above 200 m is being replaced by water with lower silicate levels from outside the sill, water below the sill at depths greater than 200 m is not being affected. The nitrate-salinity diagram clearly shows the same trend except that nitrate appears to increase with salinity in low surface waters. Phosphate (Figure 13) again duplicates this picture. River water was not measured for nutrients during this cruise but the data reported here

indicate that the river is probably a stronger source of silicate than for nitrate and phosphate relative to the levels occurring in the inlet. Looking back at the contour plots (Figures 5, 7, 9, 10, 11) one can see the intrusion of high salinity low nutrient water particularly on the silicate and nitrate diagrams. This circulation pattern probably also explains the subsurface temperature and oxygen maximums observed at the stations inside the sill. The S-T plots for all stations corroborate these conclusions and in general the maximum temperature of 8°C is found in the salinity range of 31.7°/oo - 32.0°/oo at a depth of 100-150 m with the notable exception of Station 1 where the maximum temperature is only 7.8°C and occurs at 50 m.

b) Sediments

At Station 10, one box core was obtained and has been subjected to ^{210}Pb geochronology. The core consisted of soft mud with a greenish brown appearance at the surface. The porosity decreased sharply with depth in the top 20 cm and more slowly below that. The dotted line on Figure 17 represents the data fitted to the theoretical curve given by Athy (1931). In order to compensate for the effect of compaction, the excess ^{210}Pb activity is plotted against Z', the depth corresponding to a non-compacted sediment. Examination of Figure 16 brings out several interesting features. The sedimentation rate both near the surface and at depth is about 0.47 cm y^{-1} (0.06 g $cm^{-2}y^{-1}$). Above the corrected depth of 20 cm (actual depth $\sim$ 10 cm) there is a slight flattening of the excess ^{210}Pb profile. This is probably due to bioturbation. At corrected depths of about 50 cm and 80-100 cm there are breaks in the uniform decay of excess ^{210}Pb with depth. These could arise as a result of turbidity flows as suggested by Pickard (1961). Similar disturbed profiles have been reported by Oldfield et al (1978) who interpreted these as an alteration of sedimentation rate. The effect of turbidity flows would be to increase sedimentation rate above that determined from a linear segment shown on Figure 16. It should be noted that the ^{210}Pb activities are relatively high at the surface allowing reduced counting times to achieve the necessary statistical confidence. This results in shorter analysis time and makes the area a good one for attempting geochronology. Turbidity flows will make interpretation more difficult, but not impossible. Based on the organic carbon content of this core, the flux rate of carbon to the sediment is about 1.4 mg $cm^{-2}y^{-1}$. Turbidity flows could increase this to about 2.2 mg $cm^{-2}y^{-1}$.

c) Filtering of Nutrients

At Station 8 nutrient samples were drawn in triplicate both filtered and unfiltered from all depths in order to test the effect of filtering. Data from the analysis was subjected to a two-way ANOVA (Model I) with replicates test (Zar, 1974). Factor A was depth and factor B was filtering with level one being no filter and level 2 filter. The null hypotheses are as follows:

1-Ho There is no effect of depth (Factor A) on nutrient concentration.

2-Ho There is no effect of filtering (Factor B) on nutrient concentration.

3-Ho There is no interaction of depth and filtering (AXB) on the nutrient concentration.

For all three nutrients the Fmax test was used to check for equality of variance where

$$Fmax = \frac{\sigma^2 \text{ max}}{\sigma^2 \text{ min}}$$

Two of the phosphate measurements were deleted because of an obviously erroneous measurement. The calculated test statistic along with the critical statistic (95%) is shown in column 2 of Table 5. In all three cases the variances may be assumed to be homogeneous. Factor A, the influence of depth need not be tested for our present purposes, but for the sake of interest the result of the test is shown in column 3 of Table 5. Obviously depth is an important consideration for all of the nutrients as expected. Factor B, the influence of filtering, was tested and the results are summarized in column 4. Both silicate and phosphate are unaffected by filtering, and there is no interaction between filtering and depth. However nitrate shows a statistically significant (95%) filtering effect and an examination of the original data reveals that the filtered samples have about a 1% increase in their nitrate concentration at the 20 µg at L^{-1} level. This effect is not particularly large considering the reported precision and accuracy of the method in Table 1. Millipore (MF) filters were used with the reported composition: mixed esters of cellulose, cellulose acetate and cellulose nitrate. Prior to filtering the sea water sample the filter was rinsed with 400 mL of distilled water and rinsed at least once with a small amount of the sea water to be sampled. In spite of this it appears that small amounts of nitrate were leached into the sea water during filtering. It has previously been reported that cellulose filters can add nitrate to nutrient samples (Maynard and Hopkins, 1971) and polycarbonate appears to be a better filtering material. On the whole, for non-turbid water, filtering appears to be an unnecessary step during which contamination could take place.

d) Biological Samples

The locations at which net hauls were performed are listed in Table 6, and stored material not yet analyzed is given in Table 6. Identification of material caught in the Neuston and Miller net hauls is summarized in Table 8.

CONCLUSIONS

In a physical sense the water in Kitimat Arm can be considered as a two layer system. From the point of view of the chemistry, however, at least three bodies of water appear to be important during this cruise, and other water bodies might become apparent from a longer, in-depth survey. First there is the fresh water input which is highly variable and affects the top 10-20 m directly. Sampling both in this layer and of the river proper should be attempted if a complete chemical picture is to be obtained. Second there is a subsurface layer from about 20 m down to about 200 m which appears to be

subject to exchange from outside the sill at this time of year. It is also indirectly affected by the river inflow both by particulate fall-out and because inflow is driven to some extent by estuarine flow at the surface. Chemical properties of this water will be a superposition of processes going on within the inlet on water which is of relatively recent origin from outside the inlet. Particles falling through this layer as well as biological processes going on within it could produce obvious effects on the original water. Third, there is a body of deep water below the sill which does not exchange as readily and could be affected by interaction with sediments and particulates over a longer period. Use of particle size distribution should be an excellent approach in examining the chemistry of the water, and has been used to look at trace metal interactions in the Saguenay Fjord (Chanut et al, 1977).

Geochronology of the sediments should be a valuable tool in determining horizons in sediments where anthropogenic inputs have taken place. Flux rates of natural and anthropogenic materials can both be determined, as can the rate of burying these below a depth at which bioturbation is important. High surface activity of ^{210}Pb makes it a natural choice for dating the sediments for at least the last 100 years.

A small test of the effect of filtering during sampling shows that both silicate and phosphate are unaffected in non-turbid waters. Nitrate is increased by about 1% at the 20 μg at L^{-1} level. Use of a polycarbonate filter should eliminate this effect.

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TABLES

TABLE 1

PRECISION AND ACCURACIES OF THE METHODS

Measurement	Precision	Accuracy (± 2σ Limits)
$T^{o}C$	$<.01C^{o}$	$\pm .02C^{o}$
O_2 mL L^{-1}	± .005 mL L^{-1}	± .02 mL L^{-1}
Salinity $^{o}/oo$	± .003 $^{o}/oo$	± .02 $^{o}/oo$
Organic Carbon	± 0.25%	± 3.0%
Nitrate µg at L^{-1}	± 0.4%	± 4%
Silicate µg at L^{-1}	± 0.3%	± 5%
Phosphate µg at L^{-1}	± 2% (high turbidity not filtered)	±10%
Phosphate µg at L^{-1}	± 0.3% (low turbidity or filtered)	± 5%

TABLE 2

STATION LOCATIONS

STATION	DATE	TIME:GMT	LOCATION		SAMPLING*
			N	W	
1	13.2.77	2016	52°46.8'	129°51.3'	S,T,N,O_2, XBT
2	13.2.77	1807	52°53.0'	129°30.0'	S,T,N,O_2, XBT
3	8.2.77	1827	52°57.5'	129°15.0'	S,T,N,O_2, XBT B (S)
4	8.2.77	2221	53°06.8'	129°21.8'	S,T,N,O_2, XBT
5	9.2.77	0038	53°16.5'	129°17.0'	S,T,N,O_2, XBT, B(S,D)
6	9.2.77	1650	53°00.65'	129°00.72'	S,T,N,O_2, XBT G
7	9.2.77	0332	53°16.7'	129°08.0'	S,T,N,O_2, XBT
8	9.2.77	1936	53°26.3'	129°12.6'	S,T,N,O_2, XBT G
9	9.2.77	2328	53°36.3'	129°12.7'	S,T,N,O_2
10	10.2.77	0222	53°44.0'	129°01.7'	S,T,N,O_2, B(S) G
10A	11.2.77	0038	53°46.3'	128°49.8'	XBT
10B	11.2.77	0106	53°47.0'	128°54.5'	XBT
11	10.2.77	1707	53°50.0'	128°48.0'	S,T,N,O,G
11A	10.2.77	1815	53°53.7'	128°44.7'	XBT
12	10.2.77	1932	53°58.75'	128°40.5'	S,T,N,O_2,G,B(S+D) XBT

TABLE 2 (CONTINUED)

STATION	DATE	TIME:GMT	LOCATION		SAMPLING
			N	W	
Anchor Stn	9.2.77	0725	53°04.2'	129°06.0'	G
10	11.2.77	1653	53°44.0'	129°01.7'	Box Core
BW-1	11.2.77	2330	53°04.1'	129°35.6'	Mussel Collection
BW-2	10.2.77	2050	53°58.75'	128°40.5'	" "
BW-3	10.2.77	2225	53°52.6'	128°42.6'	" "
BW-4	12.2.77	1840	54°02.2'	130°15.5'	" "
BW-5	9.2.77	2115	53°26.3'	129°10.7'	" "
BG-1	12.2.77	2100	54°12.25'	130°21.8'	G
BG-2	12.2.77	2127	54°12.17'	130°19.5'	G
BG-3	12.2.77	2147	54°13.18'	130°17.62'	G
BG-4	12.2.77	2201	54°13.9'	130°18.05'	G
BG-5	12.2.77	2213	54°13.9'	130°18.05'	G
BG-6	12.2.77	2229	54°14.3'	130°18.22'	G
BG-7	12.2.77	2236	54°14.37'	130°18.22'	G
BG-8	12.2.77	2241	54°14.44'	130°18.26'	G
BG-9	12.2.77	2247	54°14.55'	130°18.36'	G

TABLE 2 (CONTINUED)

STATION	DATE	TIME:GMT	LOCATION		SAMPLING
			N	W	
Pump Station-1	15.2.77	0015	$49^{o}26.5'$	$123^{o}59.6'$	Sea water for Hg mobilization study (Howe Sound)
Pump Station-2	15.2.77	0500	$49^{o}40.9'$	$123^{o}10.6'$	

*B - Blumer Sampler for Hydrocarbons S - Shallow D - Deep
G - Bottom Grab
N - Nutrients - Silicate, Nitrate, Phosphate
O_2 - Oxygen
S - Salinity
T - Temperature
XBT - Expendable Bathythermograph

Stations 1 - 12 and BW1 - BW5 - Kitimat Arm
Stations BG1 - BG9 - Porpoise Harbour
Pump Stations 1, 2 - Howe Sound

TABLE 3

CHEMICAL DATA

STATION #1 13/2/77 2016 GMT DEPTH 240 m

DEPTH	TEMP. (°C)	SALINITY $^{o}/_{oo}$	σ T	OXYGEN (mL L^{-1})	OXYGEN % SAT'N	PHOSPHATE (µg at L^{-1})	SILICATE (µg at L^{-1})	NITRATE (µg at L^{-1})
0	8.37	31.711	24.66	6.70	100.2	1.49	20.6	13.1
10	-	31.696	-	6.72	-	1.45	20.6	13.1
20	8.41	31.700	24.65	6.71	100.3	1.41	20.7	13.1
30	8.41	31.716	24.66	6.68	100.0	1.38	20.5	13.1
50	8.45	31.716	24.65	6.67	99.8	1.35	20.5	13.1
75	8.22	31.716	24.69	6.68	99.5	1.36	20.2	13.0
100	8.32	31.810	24.75	6.62	98.8	1.36	18.8	12.3
150	8.34	32.174	25.03	5.69	85.1	1.44	19.8	13.2
200	7.39	33.038	25.85	4.53	66.8	2.09	37.4	23.6

TABLE 3 (CONTINUED)

STATION #2 13/2/77 1807 GMT DEPTH 180m

DEPTH	TEMP (^{0}C)	SALINITY $^0/_{00}$	σ_T	OXYGEN (mL L^{-1})	OXYGEN % SAT'N	PHOSPHATE (μg at L^{-1})	SILICATE (μg at L^{-1})	NITRATE (μg at L^{-1})
0	7.85	31.425	24.52	6.61	97.5	1.62	25.9	16.2
10	7.85	31.425	24.52	6.62	97.5	1.62	25.9	16.3
20	7.86	31.424	24.52	6.65	98.0	1.57	25.9	16.3
30	7.87	31.441	24.53	6.64	97.8	1.58	25.6	16.0
50	7.87	31.448	24.53	6.65	98.1	1.57	25.6	16.0
75	7.95	31.505	24.57	6.64	98.2	1.46	24.7	15.6
100	8.00	31.611	24.64	6.58	97.4	1.55	23.8	15.3
150	8.09	31.939	24.88	6.16	91.6	1.54	24.0	15.5
165	8.08	32.006	24.94	6.01	89.4	1.55	24.9	15.7

TABLE 3 (CONTINUED)

STATION #3 8/2/77 1827 GMT DEPTH 225 m

DEPTH	TEMP (^{0}C)	SALINITY $^0/_{00}$	σ_T	OXYGEN (mL L^{-1})	OXYGEN % SAT'N	PHOSPHATE (µg at L^{-1})	SILICATE (µg at L^{-1})	NITRATE (µg at L^{-1})
0	7.18	30.550	23.92	6.34	91.5	1.65	33.9	20.8
10	7.18	30.551	23.92	6.34	91.5	1.71	33.3	20.9
20	7.19	30.558	23.93	6.34	91.5	1.60	33.5	20.7
30	7.18	30.612	23.97	6.31	91.1	1.61	32.9	20.4
50	7.29	30.789	24.10	6.20	89.9	1.67	32.3	20.1
75	7.41	30.993	24.24	6.13	89.1	1.72	31.9	19.9
100	-	31.504	-	5.88	-	1.66	30.7	19.1
150	7.86	32.192	25.12	5.27	78.0	1.73	32.1	19.8
200	7.46	32.580	25.48	4.11	60.5	2.11	43.0	25.1
215	7.32	32.680	25.57	3.77	55.3	2.22	44.2	25.1

TABLE 3 (CONTINUED)

STATION #4 8/2/77 2221 GMT DEPTH 660 m

DEPTH	TEMP (^{0}C)	SALINITY $^0/_{00}$	σ_T	OXYGEN (mL L^{-1})	OXYGEN % SAT'N	PHOSPHATE (µg at L^{-1})	SILICATE (µg at L^{-1})	NITRATE (µg at L^{-1})
0	7.07	30.270	23.72	6.53	93.9	1.61	33.8	20.4
10	7.07	30.260	23.71	6.53	93.7	1.64	34.1	20.7
20	7.11	30.516	23.90	6.36	91.7	1.73	34.0	20.6
30	7.34	30.885	24.16	6.13	89.0	1.74	33.1	20.2
50	7.59	31.259	24.42	6.04	88.3	1.74	30.5	18.7
75	8.01	31.711	24.72	6.06	89.9	1.63	27.5	17.5
100	8.04	31.799	24.78	5.98	88.8	1.59	27.3	17.3
150	7.96	32.112	25.04	5.43	80.6	1.72	30.8	19.3
200	7.62	32.388	25.30	4.59	67.7	1.97	38.8	23.1
300	7.30	32.694	25.59	3.71	54.4	2.15	48.2	27.1
400	7.23	32.780	25.66	3.46	50.7	2.20	50.1	28.1
500	7.24	32.798	25.67	3.40	49.2	2.27	50.7	28.6
600	7.22	32.813	25.69	3.34	49.0	2.05	51.2	28.7

TABLE 3 (CONTINUED)

STATION #5 9/2/77 0388 GMT DEPTH 530 m

DEPTH	TEMP (^{0}C)	SALINITY $^0/_{00}$	σ_T	OXYGEN (mL L^{-1})	OXYGEN % SAT'N	PHOSPHATE (µg at L^{-1})	SILICATE (µg at L^{-1})	NITRATE (µg at L^{-1})
0	6.92	29.893	23.44	6.66	95.1	1.72	34.3	20.2
10	6.92	29.913	23.46	6.60	94.2	1.70	34.6	20.4
20	7.00	30.355	23.79	6.37	91.4	1.75	34.8	20.6
30	7.06	30.468	23.87	6.33	91.0	1.71	33.4	20.5
50	7.38	30.969	24.22	6.10	88.6	1.74	33.4	20.1
75	7.82	31.476	24.56	5.96	87.8	1.65	30.6	18.8
100	8.02	31.807	24.79	5.89	87.3	1.59	28.3	17.8
150	7.99	32.107	25.03	5.38	79.9	1.65	32.0	19.6
200	7.83	32.308	25.21	4.90	72.6	1.81	35.9	21.4
300	7.49	32.578	25.47	3.95	58.1	2.06	44.7	26.0
400	7.26	32.751	25.64	3.47	50.9	2.78	50.0	28.0
500	7.13	32.787	25.68	3.37	49.3	2.33	52.5	28.6

TABLE 3 (CONTINUED)

STATION #6 9/2/77 1650 GMT DEPTH 567 m

DEPTH	TEMP (^{0}C)	SALINITY $^0/_{00}$	σ_T	OXYGEN (mL L^{-1})	OXYGEN % SAT'N	PHOSPHATE (µg at L^{-1})	SILICATE (µg at L^{-1})	NITRATE (µg at L^{-1})
0	6.88	29.572	23.19	6.43	91.6	1.78	35.9	21.3
10	6.98	29.831	23.38	6.34	90.6	1.80	36.2	21.4
20	7.08	30.311	23.75	6.01	86.4	1.79	36.3	21.6
30	7.23	30.666	24.01	6.09	88.1	1.79	34.5	20.8
50	7.38	30.996	24.24	5.97	86.8	1.77	33.8	20.4
75	7.71	31.568	24.64	5.66	83.3	1.79	32.2	19.8
100	7.82	31.801	24.82	5.58	82.3	1.76	31.8	19.7
150	7.69	32.182	25.10	4.91	72.0	1.77	36.9	22.1
200	7.51	32.385	25.32	4.29	63.1	1.78	41.6	24.2
300	7.25	32.652	23.56	3.68	53.9	2.18	48.3	27.3
400	7.11	32.745	25.65	3.41	49.8	2.36	50.8	28.3
500	7.08	32.772	25.68	3.35	48.9	2.39	52.0	28.6
550	7.07	32.777	25.69	3.31	48.3	2.37	52.1	28.7

TABLE 3 (CONTINUED)

STATION #7 9/2/77 0332 GMT DEPTH 520 m

DEPTH	TEMP (^{0}C)	SALINITY $^0/_{00}$	σ_T	OXYGEN (mL L^{-1})	OXYGEN % SAT'N	PHOSPHATE (μg at L^{-1})	SILICATE (μg at L^{-1})	NITRATE (μg at L^{-1})
0	6.85	29.533	23.17	6.55	93.1	1.69	35.2	20.7
10	6.86	29.639	23.25	6.49	92.4	1.74	35.3	20.7
20	6.88	29.816	23.39	6.43	91.7	1.71	35.3	21.0
30	7.06	30.244	23.70	6.05	86.9	1.72	34.9	21.0
50	7.26	30.666	24.00	5.65	81.8	1.83	34.2	21.1
75	7.68	31.334	24.47	4.78	70.9	1.76	34.2	20.8
100	7.92	31.686	24.71	3.27 ?	48.4	1.72	29.2	19.3
150	8.01	31.971	24.92	5.18	77.0	1.76	31.2	19.5
200	7.81	32.259	25.26	4.63	67.6	1.88	36.7	22.2
300	7.32	32.615	25.52	3.13	46.0	2.21	48.0	27.4
400	7.08	32.746	25.66	3.40	49.6	2.33	51.5	28.3
500	7.03	32.798	25.71	3.31	48.2	2.41	53.2	28.7

TABLE 3 (CONTINUED)

STATION #8 9/2/77 1936 GMT DEPTH 400 m

DEPTH	TEMP (^{0}C)	SALINITY $^0/_{00}$	σ_T	OXYGEN (mL L^{-1})	OXYGEN % SAT'N	PHOSPHATE (µg at L^{-1})	SILICATE (µg at L^{-1})	NITRATE (µg at L^{-1})
0	6.31	27.186	21.39	6.76	93.4	1.65	31.5	19.8
10	6.75	29.067	22.81	6.37	90.1	1.77	33.6	20.6
20	6.90	29.662	23.26	6.20	88.3	1.80	34.6	21.3
30	7.13	30.316	23.74	5.91	85.0	1.89	35.2	21.5
50	7.62	31.108	24.30	5.19	75.9	1.88	36.5	22.1
75	7.77	31.303	24.43	5.09	74.9	1.91	35.6	21.5
100	7.84	31.529	24.60	5.49	80.9	1.84	33.6	20.7
150	8.01	31.979	24.93	5.39	80.0	1.83	32.3	19.8
200	7.76	32.199	25.14	4.45	65.7	2.04	40.7	23.8
300	7.10	32.591	25.53	3.54	51.7	2.28	47.9	27.5
380	6.96	32.696	25.64	3.37	49.0	2.31	51.7	28.3

TABLE 3 (CONTINUED)

STATION #9 9/2/77 2328 GMT DEPTH 242 m

DEPTH	TEMP (^{0}C)	SALINITY $^0/_{00}$	σ_T	OXYGEN (mL L^{-1})	OXYGEN % SAT'N	PHOSPHATE (µg at L^{-1})	SILICATE (µg at L^{-1})	NITRATE (µg at L^{-1})
0	5.79	23.194	18.31	7.10	94.5	1.43	30.9	17.6
10	6.91	29.378	23.04	6.04	85.9	1.74	36.8	21.5
20	7.20	30.347	23.76	5.68	81.9	1.80	37.1	21.9
30	7.37	30.715	24.03	5.42	78.7	1.84	37.1	21.9
50	7.73	31.328	24.46	5.41	79.5	1.83	35.3	21.3
75	7.86	31.497	24.57	5.59	82.4	1.75	32.9	20.1
100	7.96	31.690	24.71	5.58	82.7	1.73	31.8	19.6
150	7.91	31.977	24.94	5.12	75.8	1.85	35.0	21.1
200	7.68	32.192	25.14	4.48	66.1	2.05	40.7	24.2
230	7.58	32.260	25.21	4.32	63.5	2.10	42.0	24.5

TABLE 3 (CONTINUED)

STATION # 10 10/2/77 0222 GMT DEPTH 380 m

DEPTH	TEMP (^{0}C)	SALINITY $^0/_{00}$	σ_T	OXYGEN (mL L^{-1})	OXYGEN % SAT'N	PHOSPHATE (µg at L^{-1})	SILICATE (µg at L^{-1})	NITRATE (µg at L^{-1})
0	5.94	24.668	19.45	6.99	94.3	1.49	32.6	18.8
10	6.84	28.769	22.57	5.92	83.7	1.75	36.5	21.3
20	7.25	30.138	23.59	5.51	79.4	1.82	37.1	22.0
30	7.49	30.858	24.12	5.33	77.6	1.84	37.1	22.2
50	7.64	31.176	24.35	5.23	76.5	1.87	36.9	22.2
75	7.87	31.489	24.56	5.41	79.8	1.81	33.9	20.7
100	8.01	31.813	24.80	5.28	78.2	1.77	33.9	20.8
150	7.78	32.091	25.05	4.33	64.0	2.01	35.3	24.5
200	7.28	32.328	25.30	3.77	55.1	2.18	46.6	26.7
300	6.77	32.661	25.63	3.37	48.9	2.42	53.2	28.5
360	6.74	32.700	25.67	3.32	48.1	2.40	55.0	28.9

TABLE #3 (CONTINUED)

STATION #11 10/2/77 1707 GMT DEPTH 336 m

DEPTH	TEMP (^{0}C)	SALINITY $^0/_{00}$	σ_T	OXYGEN (mL L^{-1})	OXYGEN % SAT'N	PHOSPHATE (µg at L^{-1})	SILICATE (µg at L^{-1})	NITRATE (µg at L^{-1})
0	4.72	20.560	16.32	7.34	93.5	1.25	37.8	17.6
10	6.99	29.740	23.31	5.54	79.2	1.83	38.4	22.3
20	7.35	30.459	23.83	5.29	76.5	1.88	38.2	22.8
30	7.46	30.784	24.07	5.23	76.0	1.88	37.9	22.8
50	7.69	31.113	24.30	5.17	75.7	1.87	37.3	22.5
75	7.93	31.438	24.52	5.13	75.8	1.86	37.5	22.8
100	8.07	31.727	24.72	4.74	70.4	1.86	36.5	22.0
150	7.70	32.033	25.01	3.95	58.2	2.25	46.4	26.4
200	7.27	32.186	25.19	3.59	52.5	2.13	43.1	25.8
300	6.72	32.655	25.64	3.40	49.1	2.28	52.8	28.5
320	6.72	32.712	25.68	3.35	48.5	2.42	53.8	28.4

TABLE #3 (CONTINUED)

STATION # 12 10/2/77 1932 GMT DEPTH 178 m

DEPTH	TEMP (^{0}C)	SALINITY $^0/_{00}$	σ_T	OXYGEN (mL L^{-1})	OXYGEN % SAT'N	PHOSPHATE (µg at L^{-1})	SILICATE (µg at L^{-1})	NITRATE (µg at L^{-1})
0	4.41	17.466	13.90	7.31	90.5	1.12	29.7	15.7
10	6.90	30.236	23.71	5.35	76.5	1.90	36.2	23.0
20	7.02	30.556	23.95	5.20	74.8	2.01	37.2	23.3
30	7.29	30.802	24.11	5.00	72.4	2.02	37.3	23.7
50	7.78	31.141	24.30	4.63	68.0	2.04	37.7	23.5
75	7.76	31.441	24.54	4.29	63.1	2.01	37.1	24.2
100	7.63	31.724	24.78	3.94	57.8	2.03	41.2	25.7
150	7.44	31.991	25.02	3.74	54.7	2.09	43.5	26.6
160	7.31	32.010	24.27	3.58	52.0	2.07	44.9	27.3

TABLE 4

^{210}Pb Data

OC-77-IS-002

Station Location: Kitimat

Water Depth:

Date Feb. 11, 1977

Corer Type: Box

Core Length: 94.5 cm

$S = 32.7\ ^{o}/oo$
$T = 6.74^{o}C$
$\rho w = 1.02567$
$\rho s = 2.58 \pm .04$

Depth (cm)	Corrected Depth (cm)	^{210}Total Pb (dpm/g-salt free)	^{210}Excess Pb (dpm/g-salt free)	Water Content (weight %)	Porosity	% Organic Carbon
0- 1.5	0 - 1.73	52.457 ± 0.392	51.047 ± 0.395	83.80	0.942	2.26
1.5- 4.5	1.73 - 6.34	49.821 ± 0.403	48.411 ± 0.406	79.50	0.920	
4.5- 7.5	6.34 - 12.1	45.034 ± 0.437	43.624 ± 0.440	77.58	0.910	
7.5-10.5	12.1 - 18.6	37.023 ± 0.336	35.613 ± 0.339	74.27	0.892	
10.5-13.5	18.6 - 25.6	29.575 ± 0.249	28.165 ± 0.254	71.67	0.877	
13.5-16.5	25.6 - 33.1	20.537 ± 0.179	19.127 ± 0.185	69.71	0.866	
16.5-19.5	33.1 - 40.7	13.332 ± 0.096	11.922 ± 0.107	70.54	0.871	
19.5-22.5	40.7 - 48.6	15.292 ± 0.162	13.882 ± 0.169	69.34	0.863	1.67
22.5-25.5	48.6 - 56.5	5.519 ± 0.071	4.109 ± 0.071	71.10	0.874	
25.5-28.5	56.5 - 64.6			70.31	0.869	
28.5-31.5	64.6 - 72.7	3.843 ± 0.069	2.433 ± 0.084	71.01	0.873	1.69
31.5-34.5	72.7 - 80.8	3.781 ± 0.068	2.311 ± 0.083	70.49	0.870	1.80
34.5-37.5	80.8 - 88.9	5.806 ± 0.049	4.396 ± 0.069	70.45	0.870	
40.5-43.5	97.1 - 105.3	3.773 ± 0.068	2.363 ± 0.083	69.99	0.867	
46.5-49.5	113.5 - 121.7	1.931 ± 0.052	0.521 ± 0.071	68.83	0.860	

TABLE 4 (CONTINUED)

Depth (cm)	Corrected Depth (cm)	^{210}Pb Total (dpm/g-salt free)	^{210}Pb Excess (dpm/g-salt free)	Water Content (weight %)	Porosity	% Organic Carbon
52.5-55.5	129.9 - 138.2	1.588 ± 0.037	0.178 ± 0.061	70.67	0.871	
64.5-67.5	162.8 - 171.0	1.820 ± 0.028	0.410 ± 0.056	68.58	0.859	
76.5-79.5	195.7 - 203.9			67.84	0.854	
88.5-91.5	228.6 - 236.8			67.66	0.853	
91.5-94.5	236.8 - 245.0	1.410 ± 0.048		67.67	0.853	1.74

TABLE 5

ANOVA NUTRIENT RESULTS (F FACTORS)

Nutrient	Homogeneity of Variance	Factor A Depth	Factor B Filtering	Interaction AXB
Silicate	419.5/1412	123/2.06	0.44/4.06	0.27/2.06
Nitrate	6.7/1412	300/2.06	4.8/4.1	0.36/2.06
Phosphate	45/1011	94/2.32	0.8/4.1	0.12/2.3

TABLE 6

NET HAULS

#	DEPTH(m)	DATE	START	FINISH	DISTANCE NAUT. MILES	COMMENTS
*MNT-1	7,13,19,25	9.2.77	53°16.7'N 129°08.0'W 0522 GMT	53°06.5'N 129°07.2'W 0556 GMT	2.5	Combined
MNT-2	7,13,19,25	10.2.77	53°44.0'N 129°01.7W 0452 GMT	53°47.0'N 128°54.5'W 0552 GMT	2.5	Combined
NNT-1	Surface	8.2.77	51°10.0'N 128°26.0'W 0600 GMT	51°08.3'N 128°23.0'W 0630 GMT	2.5	Tar Balls + Plastic
NNT-2	Surface	12.2.77	53°05.0'N 129°33.7'W 0007 GMT	53°07.3'N 129°36.0'W 0037 GMT	2.5	No Tar
NNT-3	Surface	10.2.77	53°55.2'N 128°44.7'W 2305 GMT	53°56.9'N 128°41.15'W 2338 GMT	2.5	No Tar
NNT-4	Surface	12.2.77	54°11.52'N 130°25.25'W 2014 GMT	54°11.7'N 130°23.6'W 2045 GMT	2.5	No Tar

*MNT - Miller Net Tow

NNT - Neuston Net Tow

TABLE 7

PRESERVED MATERIAL

IDENTIFICATION	SAMPLER	SAMPLE	METHOD OF PRESERVING
BW-1	Manual Collection	Mussels (Mytilus edulis)	Frozen in Aluminum Foil
BW-2	" "	Mytilus edulis Mytilus californianus	" " " "
BW-3	" "	Mussels (Mytilus edulis)	" " " "
BW-4	" "	" "	" " " "
BW-5	" "	" "	" " " "
MNT-1	Miller Net #6 mesh	Plankton	5% Formaldehyde (Biological Identification)
MNT-2	Miller Net #6 mesh	Plankton	Frozen in Al Can Subsample for Biological ID
NNT-1	Neuston Net	Neuston	5% Buffered Formaldehyde (Biological Identification)
NNT-2	"	"	" " " "
1 5L Glass	Blumer	Sea Water 5 m	$HgCl_2$ (Hydrocarbon Analysis)
2 " "	"	" " 150 m	" " " "
3 " "	"	" " 5 m	" " " "
4 " "	"	" " 5 m	" " " "
5 " "	"	" " 150 m	" " " "
6 " "	"	" " 5 m	" " " "
7 " "	"	" " 150 m	" " " "
Anchor Stn	Ponar Grab	Mud	Al Can Frozen Whirl-Pak Bag Frozen
STD-6	"	"	" " "
STD-8	"	"	" " "

TABLE 7 (CONTINUED)

PRESERVED MATERIAL

IDENTIFICATION	SAMPLER	SAMPLE	METHOD OF PRESERVING
STD-10	Ponar Grab	Mud	Al Can Frozen Whirl-Pak Bag Frozen
STD-11	"	"	" " "
STD-12	"	"	" " "
BG-1	"	Green-Brown Mud	Al Can (Frozen for PCB Analysis
BG-2	"	Blackish Mud	" " "
BG-4	"	Black Mud (H_2S)	" " "
BG-5	"	" " "	" " "
BG-6	"	" " "	" " "
BG-7	"	" " "	" " "
Box Core STD-10	Sutar Bruland Box Corer	Mud	Subsampled into Whirl-Pak Bags, Frozen
Carboy 24	Pump	Sea Water (13m) S ≃ 28 °/oo	Stored in Polyethylene Barrel (200 L)
Carboy 20	"	Sea Water 1.5 m S ≃ 20 °/oo	" " "
Carboy 21	"	" " "	" " "
Carboy 22	"	" " "	" " "
Carboy 23	"	" " "	" " "

TABLE 8

BIOLOGICAL IDENTIFICATION

SAMPLE NO. OC-77-IS-002-NNT-1

PHYLUM	CLASS	ORDER	SPECIES	COUNT	PERCENT OF TOTAL
Chaetognatha			Saggita elegans	8	0.3
Chordata	Pisces		all larvae	152	6.0
Arthropoda	Crustacea-Copepoda-Calanoida		Metridia lucens		
			Calanus pacifica		
			Paracalanus parvus		
			Oithona helgolandica		
			Others (<2mm)	1880	74.6
			Epilabidocera amphitrites	184	7.3
			Others (>2mm)	232	9.2
		Amphipoda-Gammaridea	(juvenile stages)	40	1.6
	Malacostraca Euphausiacea		Thysanoessa spinifera	24	0.9
			TOTAL ORGANISMS PER SAMPLE	2520	

miscellaneous material

nemertean worm
fish scales
fir leaves
Macrocystis bulb and stipe
insect pupa

TABLE 8 (CONTINUED)

SAMPLE NO. OC-77-IS-002-MNT-2
2052 9/2/77

PHYLUM	CLASS	ORDER	SPECIES	COUNT	PERCENT OF TOTAL
Chaetognatha			Saggita elegans	8	0.2
Chordata	Pisces		all larvae	8	0.2
Arthropoda	Crustacea	Ostracods	Conchoecia elegans	120	3.7
	Malacostraca	Euphausacea	Euphausia pacifica	72	2.2
			Thysanoessa raschii	8	0.2
	Crustacea Amphipoda-Hyperiidae		Parathemisto sp.	16	0.5
		Gammaridae	Cyphocaris sp.	24	0.7
	Crustacea-Copepoda-Calanoida		Metridia lucens	1416	43.3
			Metridia okhotensis	592	18.1
			Candacia bipinnata	16	0.5
			Others (<2mm)	992	30.3
			TOTAL ORGANISMS PER SAMPLE	3272	

SAMPLE NO. OC-77-IS-002-NNT-2
1607 11/2/77

Chordata	Pisces	all larvae	152	3.1
Arthropoda	Crustacea Amphipoda-Gammaridae	Parathemisto sp.	1232	24.9
	Crustacea-Copepoda-Calanoida	all <2mm	3512	71.0
		Epilabidocera amphitrites	48	
		TOTAL ORGANISMS PER SAMPLE	4944	

miscellaneous material
polychaete worm tubes
grass
algae blade
cedar leaves
feathers
fir leaves

TABLE 8 (CONTINUED)

SAMPLE NO. OC-77-IS-002-MNT-1
2122 8/2/77

PHYLUM	CLASS	ORDER	SPECIES	COUNT	PERCENT OF TOTAL
Chaetognatha			Saggita elegans	4	0.1
Arthropoda-Crustacea-Ostracoda-Myodocopoda			Conchoecia elegans	80	1.5
	Malacostraca	Euphausiacea	Euphausia pacifica	52	1.0
			Thysanoessa raschii	4	0.1
			Thysanoessa spinifera	4	0.1
	Crustacea Amphipoda-Hyperiidae		Parathemisto sp.	8	0.2
		Mysidacea		12	0.2
	Crustacea-Copepoda-Calanoida		Metridia lucens	3152	57.5
			Metridia okhotensis	160	2.9
			Candacia bipinnata	48	0.8
			Calanus pacificus	80	1.5
			Others (<2mm)	1872	34.1
			TOTAL ORGANISMS PER SAMPLE	5312	

FIGURES

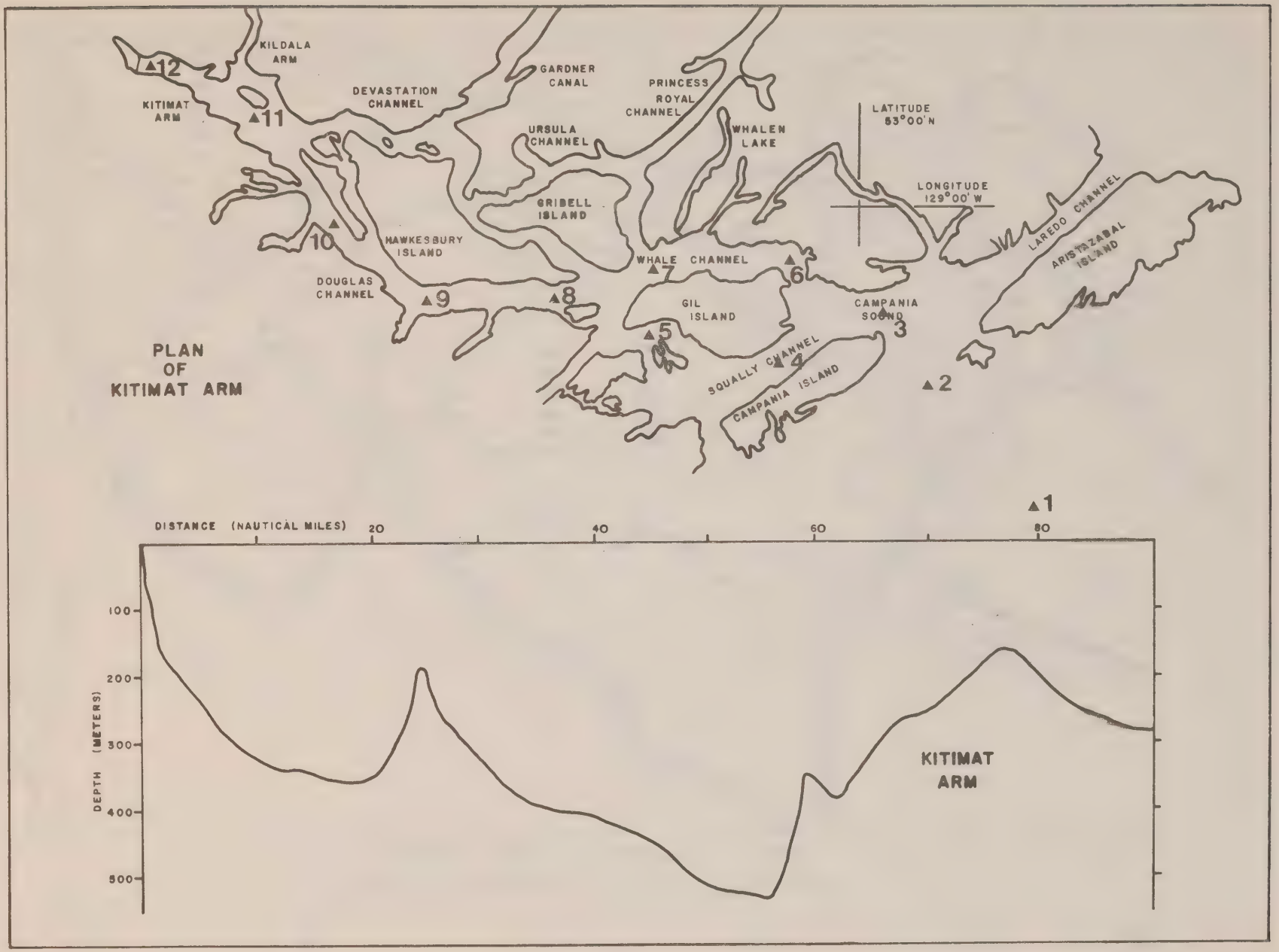
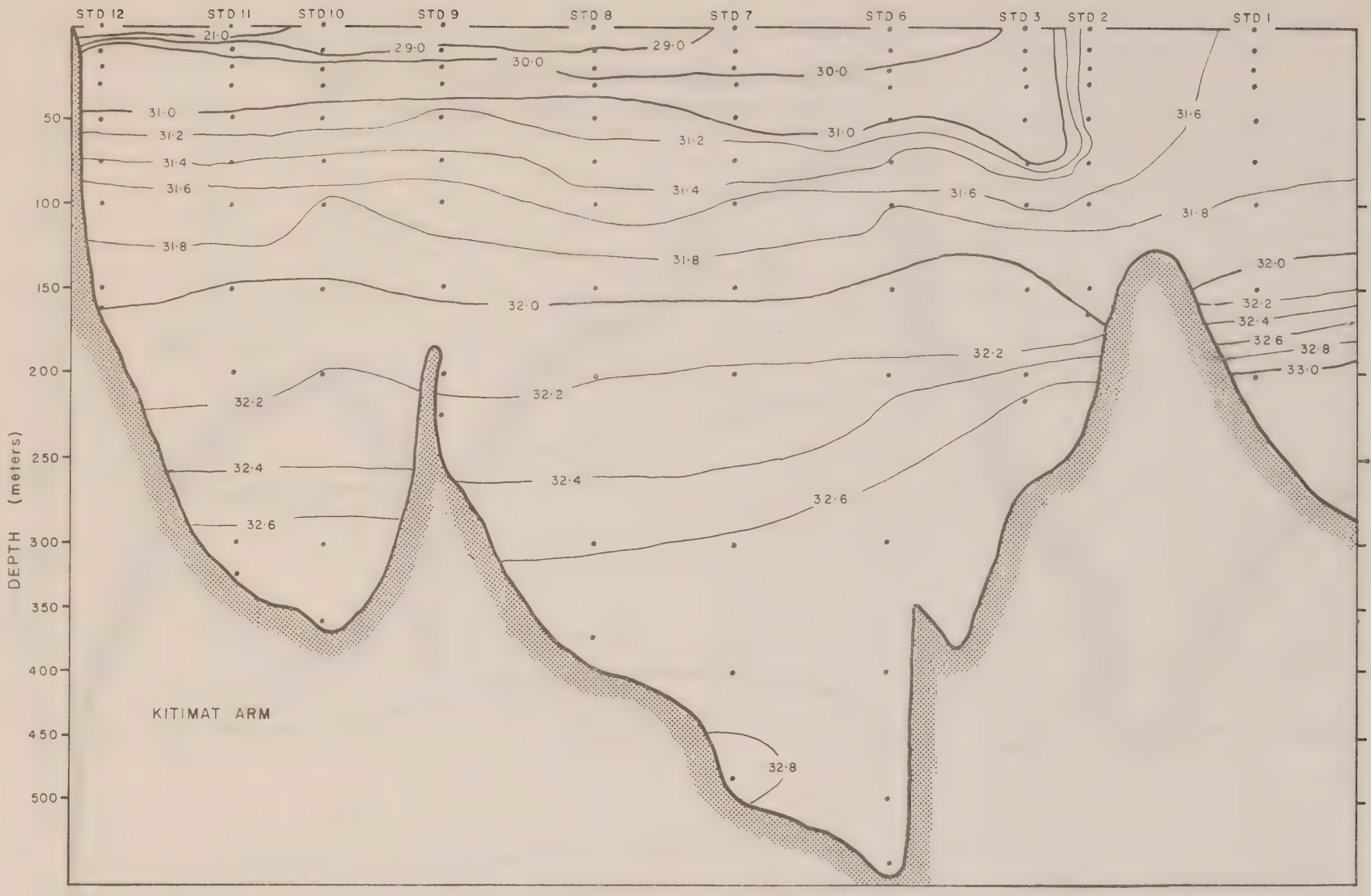

KILDALA ARM
KITIMAT ARM
DEVASTATION CHANNEL
GARDNER CANAL
PRINCESS ROYAL CHANNEL
URSULA CHANNEL
WHALEN LAKE
LATITUDE 53°00'N
LONGITUDE 129°00' W
GRIBELL ISLAND
HAWKESBURY ISLAND
WHALE CHANNEL
LAREDO CHANNEL
ARISTAZABAL ISLAND
DOUGLAS CHANNEL
GIL ISLAND
CAMPANIA SOUND
SQUALLY CHANNEL
CAMPANIA ISLAND
PLAN OF KITIMAT ARM
DISTANCE (NAUTICAL MILES)
20
40
60
80
DEPTH (METERS)
100
200
300
400
500
KITIMAT ARM

Figure 1


B.G.0
B.G.8
B.G.7
B.G.6
WATSON
ISLAND
PORPOISE HARBOUR
B.G.5
RIDLEY
ISLAND
B.G.4
Coast I.
Gayl
B.G.3
B.G.2
B.G.1
LELU
ISLAND
2 2'
13 20'
8'

Figure 2



KITIMAT ARM FEBRUARY 1977
VERTICAL PROFILE FOR SALINITY (‰)

Figure 3


KITIMAT ARM FEBRUARY 1977
VERTICAL PROFILE FOR DENSITY (Sigma T)
DEPTH (meters)
KITIMAT ARM
STD 12
STD 11
STD 10
STD 9
STD 8
STD 7
STD 6
STD 3
STD 2
STD 1
15
2.0
23.0
23.5
24.0
24.5
25.0
25.5
0
50
100
150
200
250
300
350
400
450
500

Figure 4


KITIMAT ARM FEBRUARY 1977
VERTICAL PROFILE FOR TEMPERATURE (C)
DEPTH (meters)
KITIMAT ARM
STD 1
STD 2
STD 3
STD 6
STD 7
STD 8
STD 9
STD 10
STD 11
STD 12
8·0
7·5
7·0
6·0
5·0

Figure 5

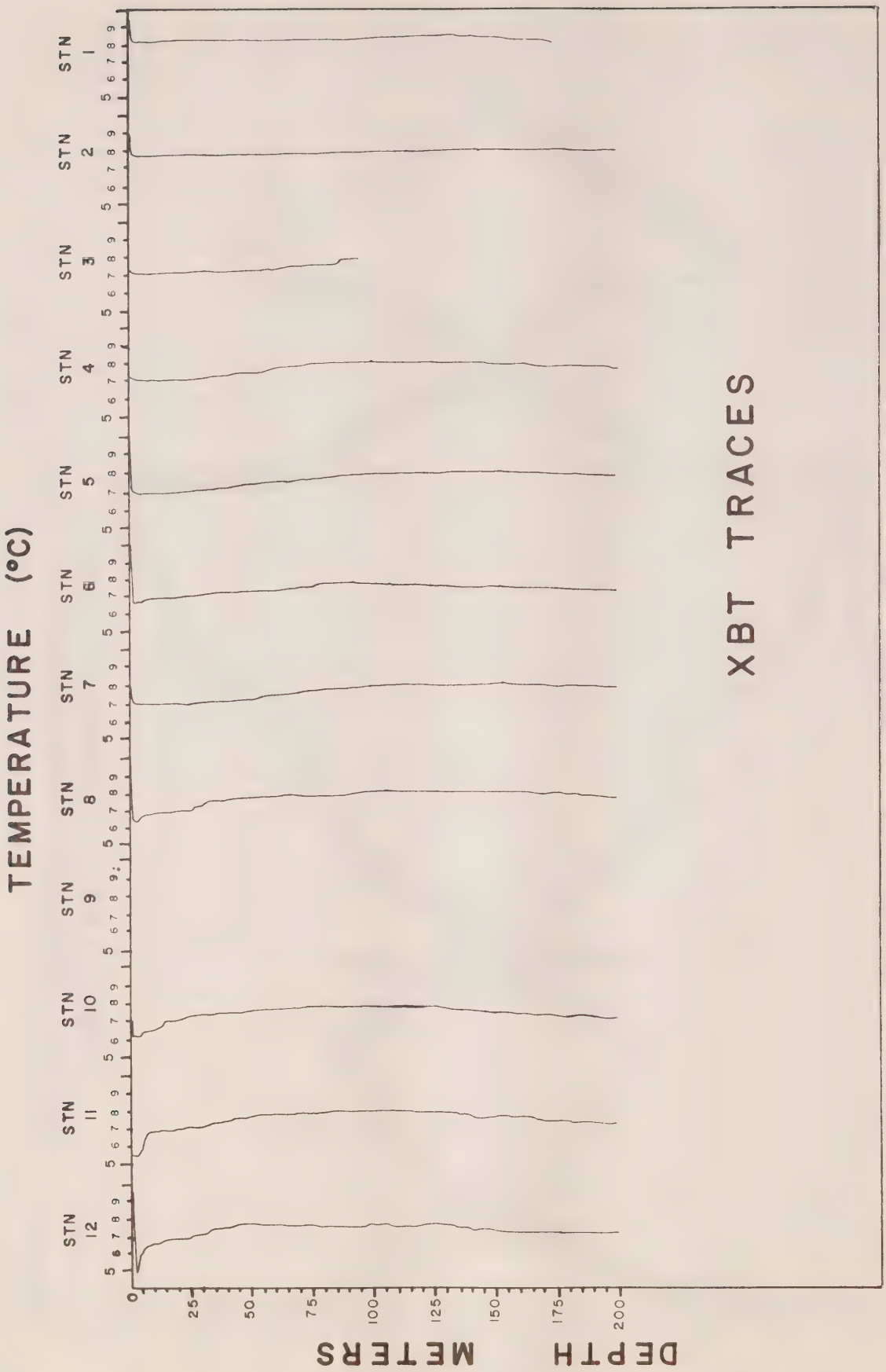

TEMPERATURE (°C)
STN 12
STN 11
STN 10
STN 9
STN 8
STN 7
STN 6
STN 5
STN 4
STN 3
STN 2
STN 1
DEPTH METERS
0
25
50
75
100
125
150
175
200
XBT TRACES

Figure 6


STD 12
STD 11
STD 10
STD 9
STD 8
STD 7
STD 6
STD 3
STD 2
STD 1
DEPTH (meters)
50
100
150
200
250
300
350
400
450
500
KITIMAT ARM
KITIMAT ARM FEBRUARY 1977
VERTICAL PROFILE FOR OXYGEN (ml/l)

Figure 7

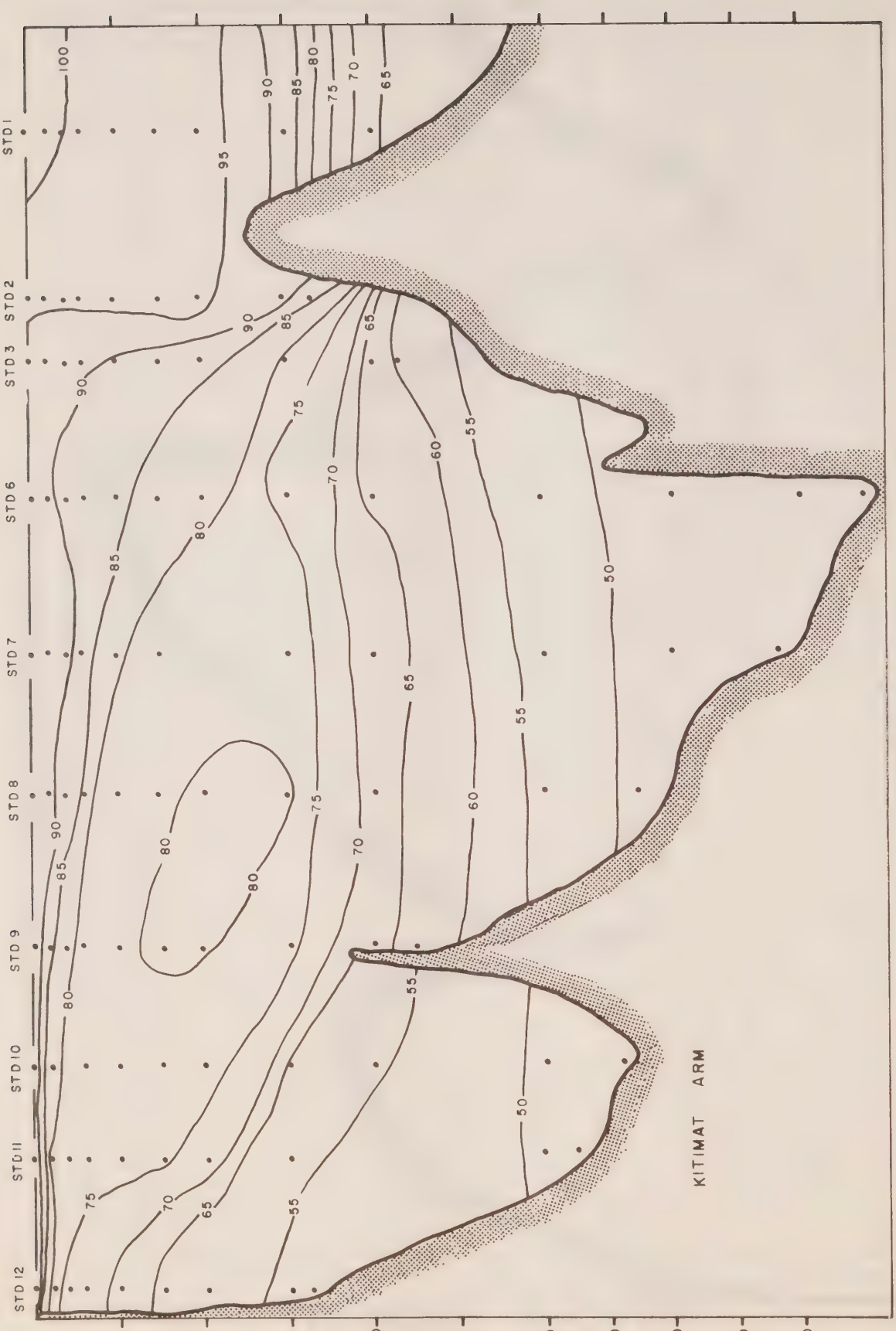

KITIMAT ARM FEBRUARY 1977
VERTICAL PROFILE FOR OXYGEN (% Sat.)
KITIMAT ARM
DEPTH (Meters)
STD 1
STD 2
STD 3
STD 6
STD 7
STD 8
STD 9
STD 10
STD 11
STD 12

Figure 8

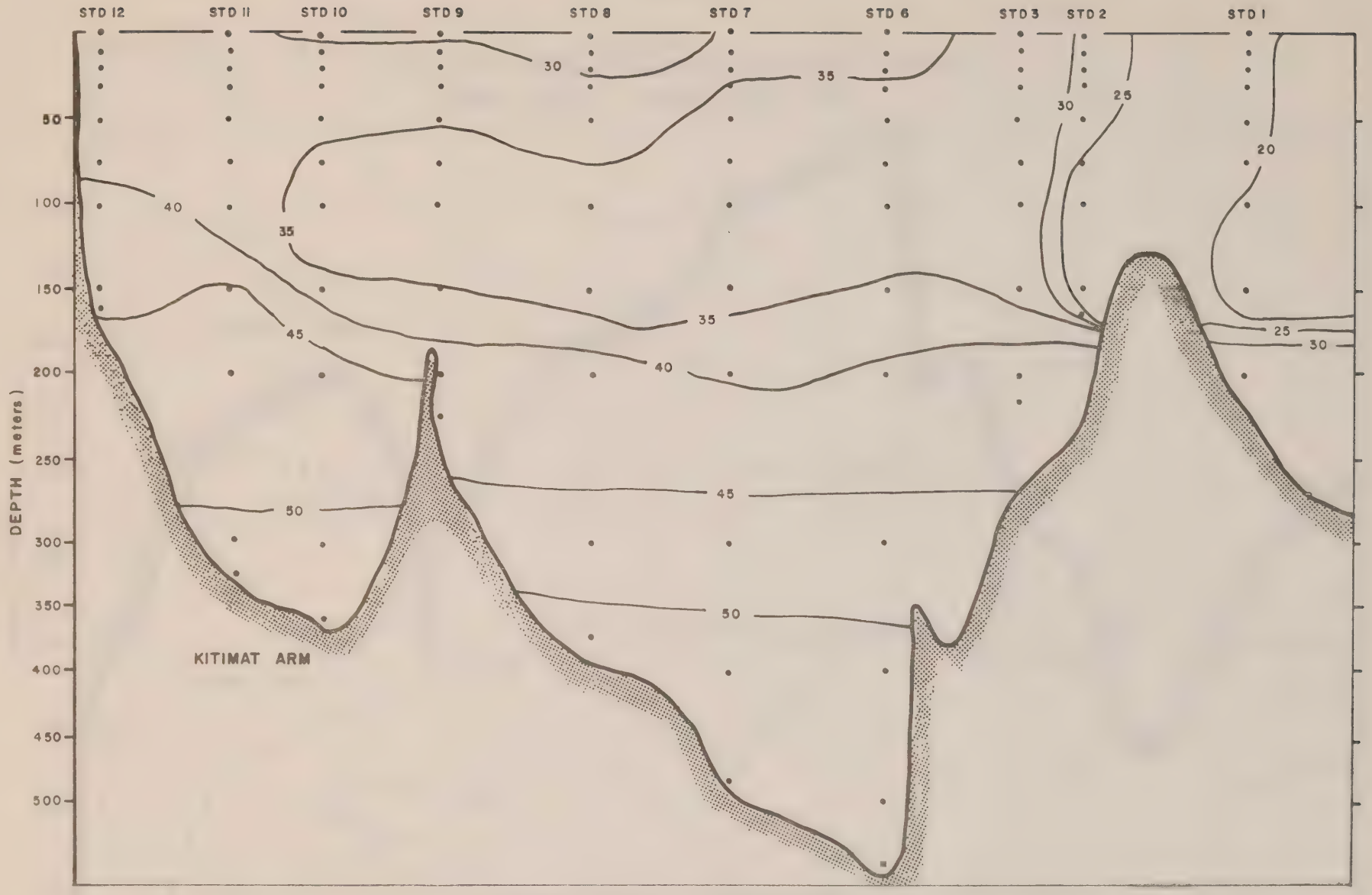

STD 12
STD 11
STD 10
STD 9
STD 8
STD 7
STD 6
STD 3
STD 2
STD 1
DEPTH (meters)
50
100
150
200
250
300
350
400
450
500
30
35
40
45
50
KITIMAT ARM
KITIMAT ARM FEBRUARY 1977
VERTICAL PROFILE FOR SILICATE (µg At/l)

Figure 9

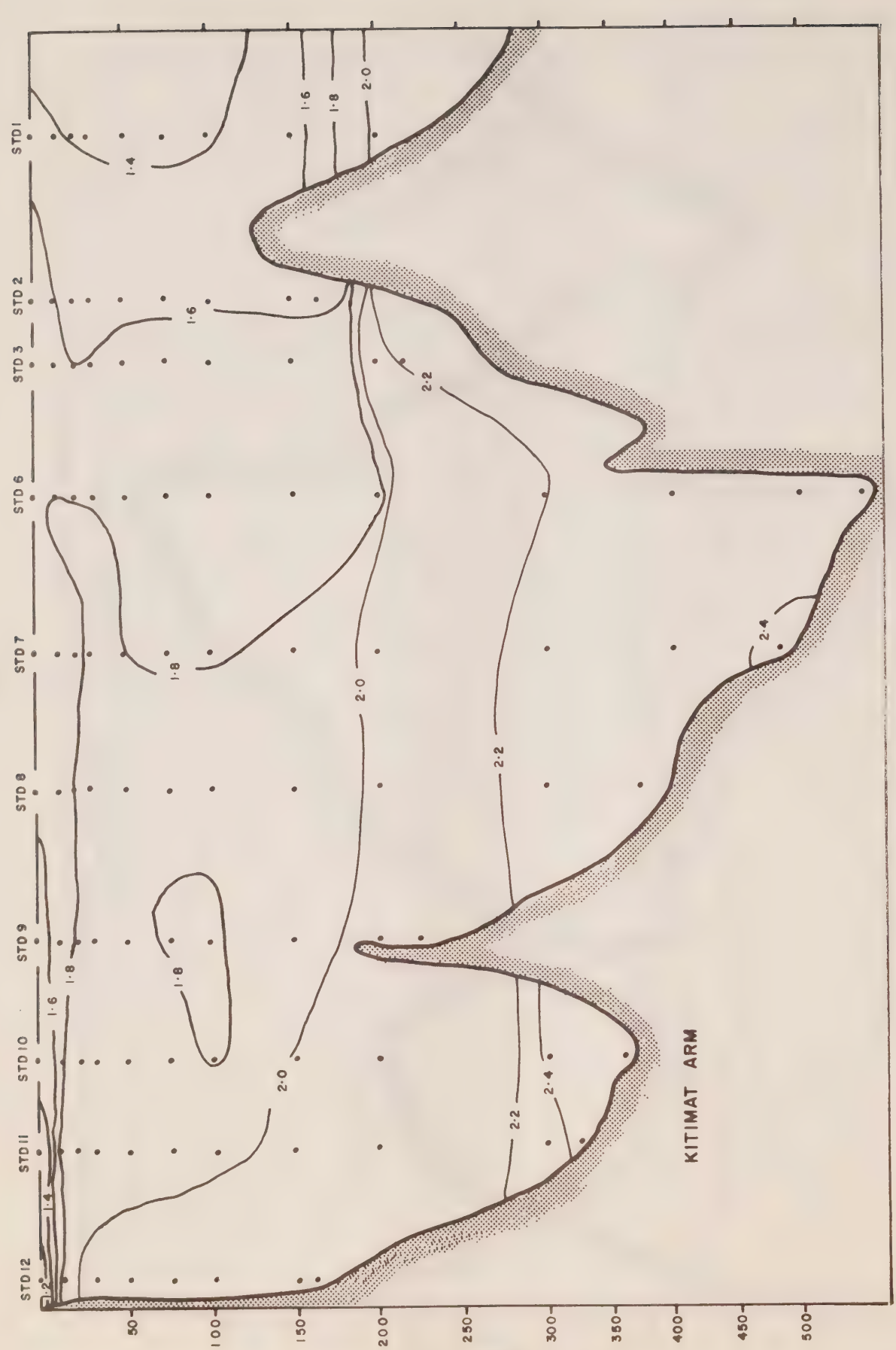
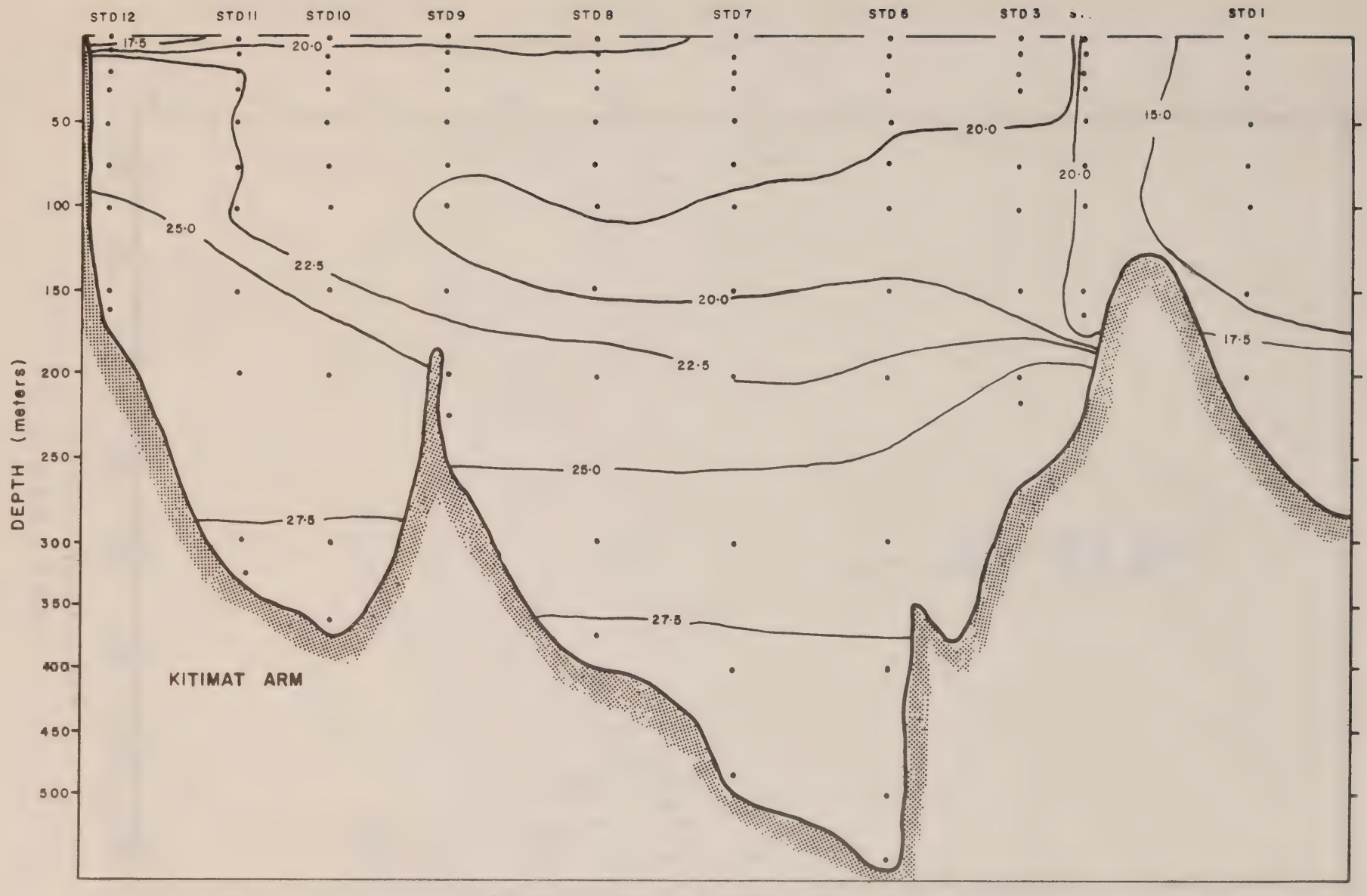

KITIMAT ARM FEBRUARY 1977
VERTICAL PROFILE FOR PHOSPHATE (µg.At./l)
KITIMAT ARM
DEPTH (meters)
STD 1
STD 2
STD 3
STD 6
STD 7
STD 8
STD 9
STD 10
STD 11
STD 12
1·4
1·6
1·8
2·0
2·2
2·4
50
100
150
200
250
300
350
400
450
500

Figure 10



KITIMAT ARM FEBRUARY 1977
VERTICAL PROFILE FOR NITRATE (µg At/l)

Figure 11


KITIMAT ARM
SALINITY ‰
SILICATE µg at L⁻¹
32
30
28
26
24
22
20
18
15
20
25
30
35
40
45
50
55
60

Figure 12


KITIMAT ARM
SALINITY ‰
32
30
28
26
24
22
20
18
1·2
1·4
1·6
1·8
2·0
2·2
PHOSPHATE ug at L⁻¹

Figure 13

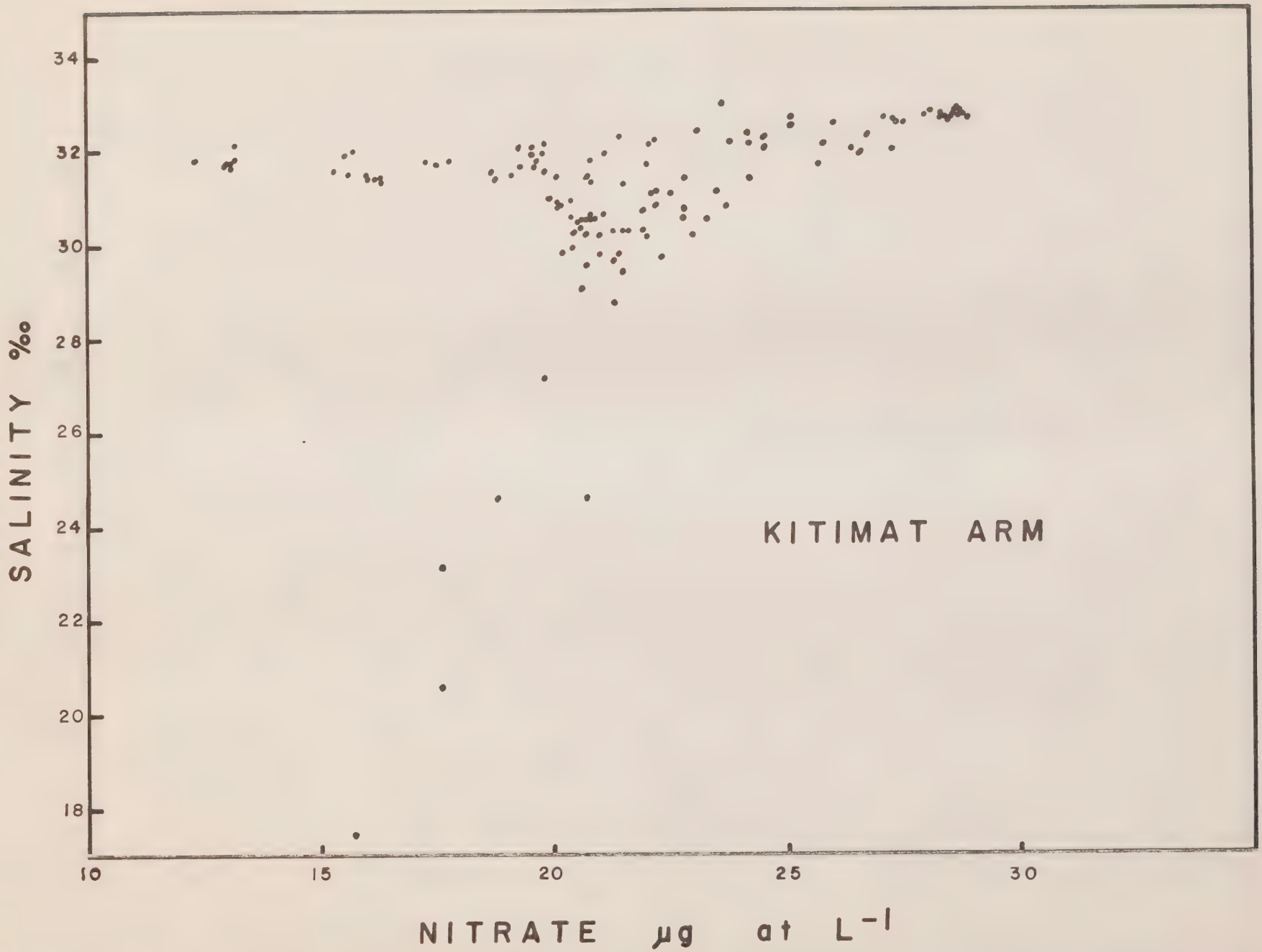

SALINITY ‰
34
32
30
28
26
24
22
20
18
KITIMAT ARM
10
15
20
25
30
NITRATE µg at L⁻¹

Figure 14

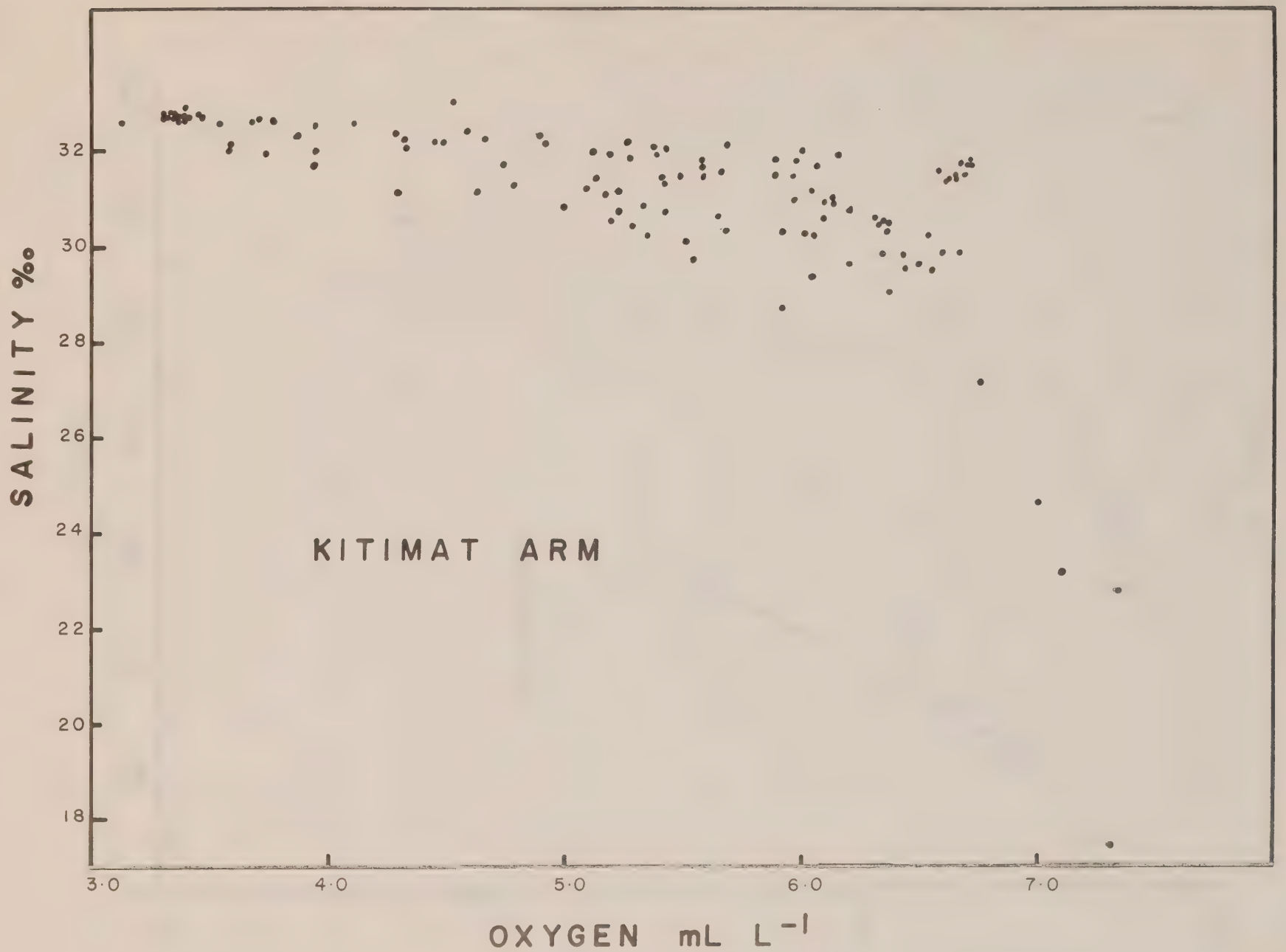

SALINITY ‰
32
30
28
26
24
22
20
18
KITIMAT ARM
3·0
4·0
5·0
6·0
7·0
OXYGEN mL L⁻¹

Figure 15

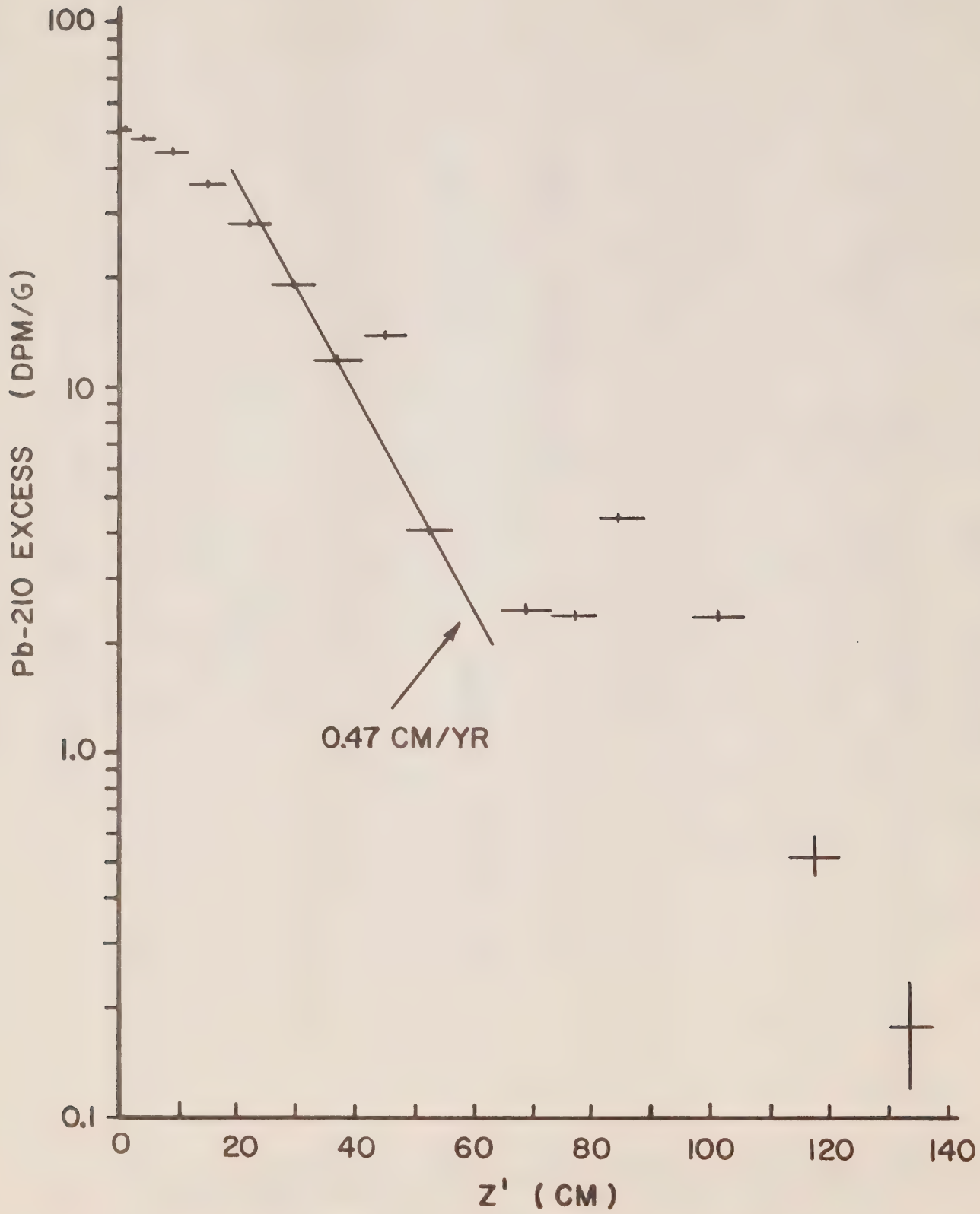

100
10
1.0
0.1
Pb-210 EXCESS (DPM/G)
0.47 CM/YR
0
20
40
60
80
100
120
140
Z' (CM)

Figure 16

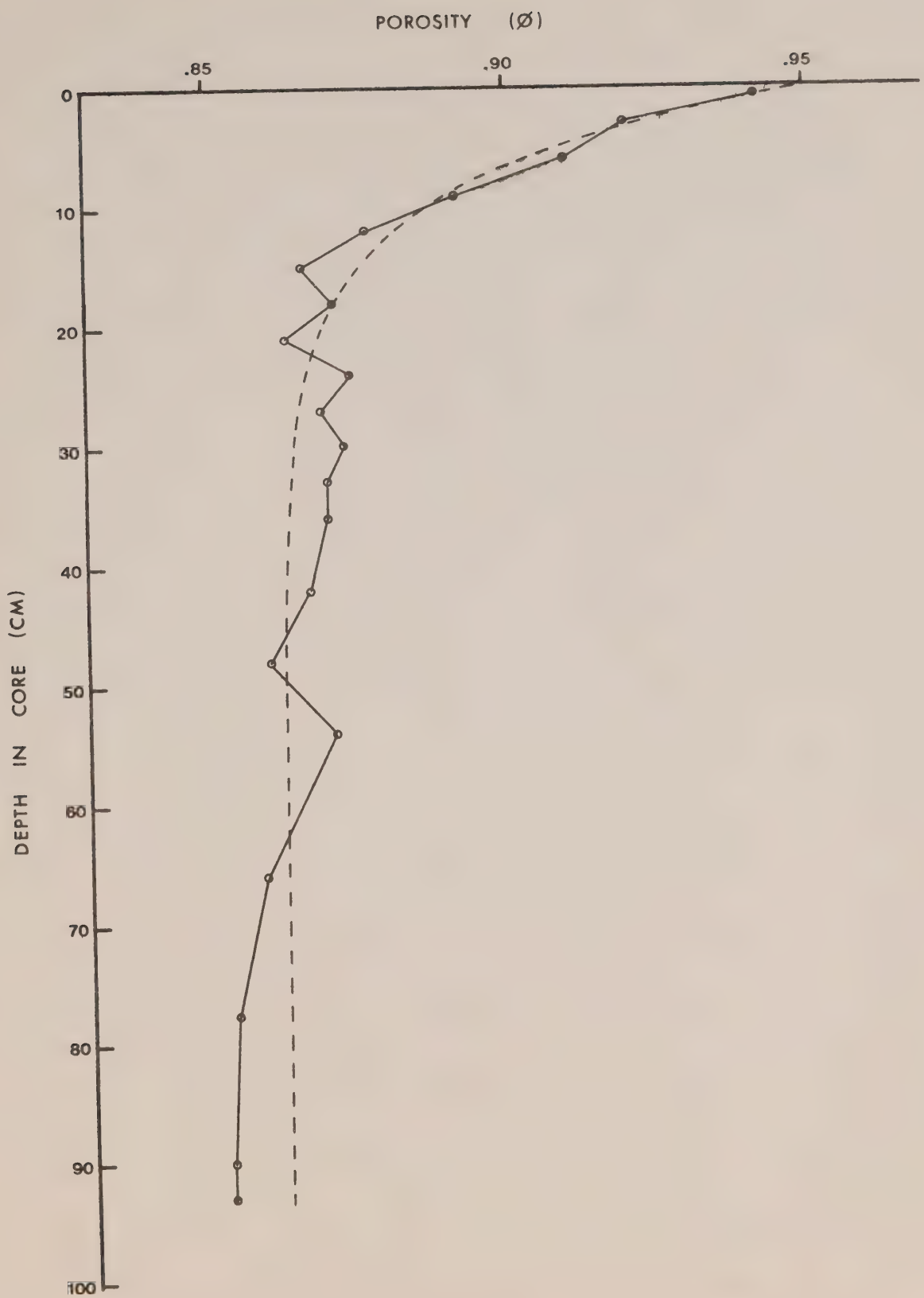

POROSITY (Ø)
.85
.90
.95
0
10
20
30
40
50
60
70
80
90
100
DEPTH IN CORE (CM)

Figure 17

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EP321
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Pacific Marine Science Report 78-25

EXTENDING THE BATHYMETRIC CAPABILITY OF THE M.V. PANDORA II

UCSB
JAN
UNIVERSITY OF

by

John V. Watt

INSTITUTE OF OCEAN SCIENCES, PATRICIA BAY
Sidney, B.C.
1978

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Abstract

Underhull aeration placed a severe limitation on the depth measurement capabilities of the M.V. Pandora II. The Institute of Ocean Sciences, Patricia Bay, was successful in overcoming this problem by extending the transducer below the ship's hull.

M.V. Pandora II

The M.V. Pandora II, a 2200 metric ton vessel on long-term charter to the Institute of Ocean Sciences (IOS), serves as a platform for a variety of oceanographic, geological, geophysical and hydrographic activities, in addition to operating as a mothership for the IOS submersible, Pisces IV.



Figure 1. M.V. Pandora II.

Originally intended for oil exploration operations in the Arctic, the Pandora II has the basic design characteristics of an ice-strengthened offshore drill rig support vessel. She is owned and operated by Christensen Canadian Enterprises Ltd., of Halifax, Nova Scotia.

From the commencement of her charter in March of 1974 to late 1976 she supported a variety of programs including the Beaufort Sea Project, University of British Columbia and University of Victoria oceanographic activities, Pisces IV operations, tidal and current survey operations and the physical,

chemical and biological oceanographic activities of the Institute.

Requirements for Deep-Sea, Precision Bathymetry

The success of this vessel as a multi-disciplinary platform, coupled with her superb capability, shown during the Beaufort Sea Project, for operating in arctic waters, resulted in the selection of the Pandora II for a 1977 hydrographic and resource survey in the Canadian western Arctic. Prior to this scheduled program there had been no specific requirement for a deep sea, precision bathymetric capability aboard this ship. In preparation for this cruise therefore, a precision depth sounding system was acquired and fitted.

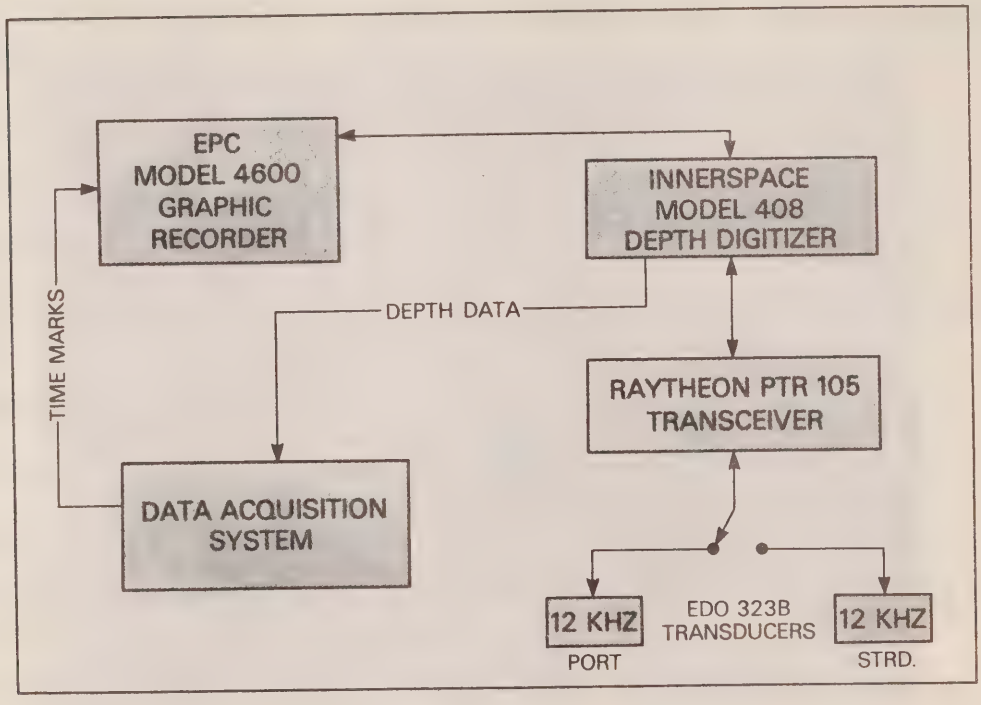


Figure 2. A block diagram of the bathymetry system fitted aboard Pandora II.

Echo sounder transducers were fitted on both the port and starboard sides of the ship's hull in a midship position. The transducers penetrated the hull and were mounted in fairings which were designed to effect minimum protrusion and maximum protection against ice damage.



Figure 3. The port echo sounder transducer as fitted aboard Pandora II. (Face is grease coated while in drydock.)

Aeration Obstructs Bathymetry

The 1977 Western Arctic operations aboard the Pandora II were fortunately very successful. "Very successful" since the majority of the objectives were either met or exceeded. "Fortunately" since, in order to meet these objectives, relatively calm seas were required and were in fact prevalent during this period of operation. On the few occasions when other than calm seas were encountered, the depth measurement system provided only sporadic information. This problem became increasingly severe as the cruise progressed, leading to the inability to obtain ocean depth measurements on the homeward bound leg across the north Pacific Ocean.

The cause of the problem was identified as an aeration effect. The flat, broad bow and fairly flat bottom of the vessel, so instrumental in her successful operations in ice, were causing severe bubble sweep down from the bow wave and heavy aeration when slamming and rolling was experienced. This aerated water was being trapped under the hull and resulted in such severe attenuation of the acoustic signal transmitted and received by the bathymetry system, that measurements were often not possible, a problem which worsened as the cruise progressed and the ship lightened through consumption of fuel.

The Pandora II was scheduled to be assigned to the 1978 hydrographic and resource survey program in the western Arctic. It was essential that a precision, deep-sea bathymetry system on Pandora II be provided. The system would therefore require modification to avoid the aeration problem and to ensure an all-weather capability.

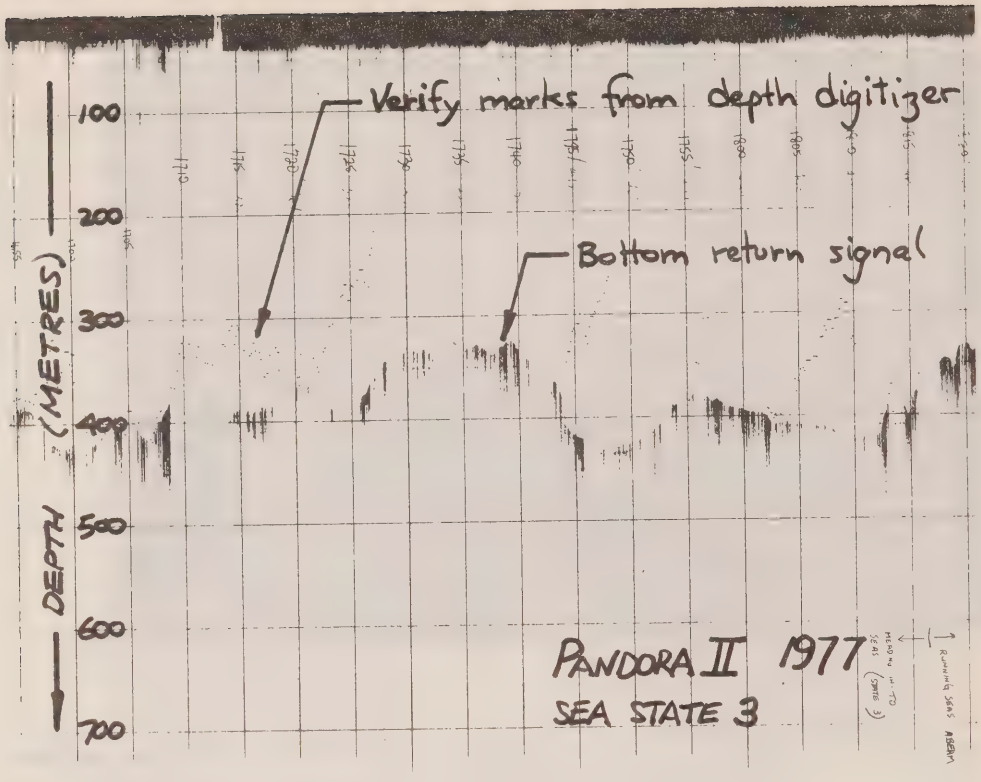


Figure 4. A representative echogram sample acquired during sea state 3 conditions (1metre wave height) in Sept. 1977.

Obviously the modifications would have to be made to the transducer installation since any hull-form modifications which would improve the situation would reduce her ice handling capabilities and would involve prohibitively high costs. Towed-body mounted transducers, retractable (through the hull) transducers, blister mounted transducers and over-the-side, leg-mounted transducers were among the approaches considered to the solution of the problem. On the basis of operational considerations such as ice breaking and therefore ice damage; heavy seas and therefore large dynamic loading, and the present congested situation with other towed bodies such as magnetometer, hydrophone arrays and air guns, the retractable transducer concept was adopted.

Location and Depth Extension

A possible location was identified in a forward tank immediately aft of the bowthruster compartment. This location was in fact one of only two possible locations which would permit an installation of the size envisaged without excessive, costly modification to the ship's general arrangement. It was selected as the primary location because it was the most forward location and therefore likely to be less susceptible to bubble sweep-down effects. Tests at sea, designed to provide information which would define the depth of transducer extension necessary to avoid aeration in this location, were programmed into an already full ship's schedule.

A tripod was designed and fitted to brackets welded by divers to the underside of the ship. Transducers, attached to the tripod, pointed upwards at the hull of the ship, and high resolution, 200 KHz, echo sounders were employed to measure the depth to the interface between clear and aerated water. The equipment was successfully tested in Saanich Inlet where the technique proved effective. Depths of aerated water were found to extend from 15 to 30 cm below the hull when small waves, 60 to 70 cm peak-to-trough in magnitude, were incident on the beam. "Murphy's Law" then got into the act; while en route to open water to measure rough water effects the ship struck a submerged log, tearing away the conduit which routed the cables up the side of the ship to the recording equipment. The transducer cables were sheared and, with the tight ship's schedule, there was not sufficient time to make repairs and proceed with the test.

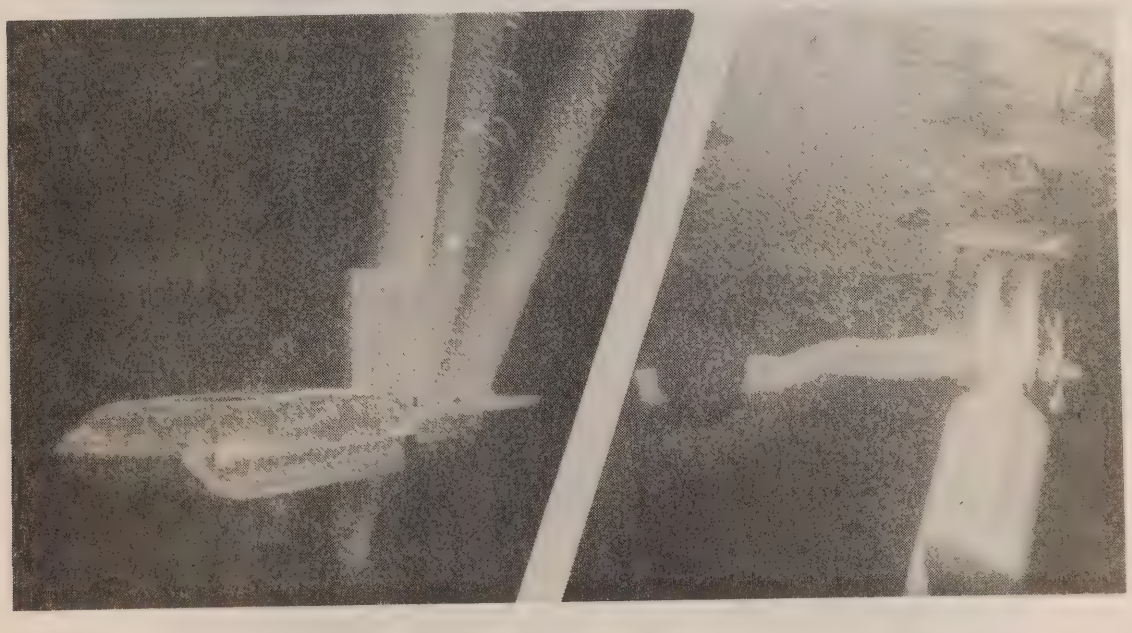


Figure 5. The tripod fitted to the hull of Pandora II in an effort to measure the depth of the aerated layer below the ship.

Time had run out! The decision regarding the location and the extent of travel of a retractable transducer now had to be made without knowledge of the depth of aeration below the vessel. The decision was made to proceed with the fitting of an extendible transducer system which would provide a maximum extension of two metres.

Fitting the Retractable Transducer

A basic specification was prepared and, at the request of IOS, the firm of Wm. R. Brown and Associates Ltd. of North Vancouver, B.C. was engaged by the owners' agent, C.R. Ward and Associates Ltd. of Sidney, B.C. to design a retractable device and structural modifications to the ship. This would permit the extension of an EDO 323-B, 12 KHz, acoustic transducer

to a maximum depth of two metres below the keel and to be retractable through a 50 cm gate valve in the hull of the M.V. Pandora II. Control stations were to be installed on the bridge, in the after laboratory (Hydrographic data acquisition centre) and in the bow thruster compartment. Each of the three stations was to provide infinite extension and retraction control over the specified range and a readout to indicate the distance which the carrier tube has been extended. Wm. R. Brown and Assoc. designed and prepared drawings for the retractable transducer utilizing a simple but innovative approach.



Figure 6. View of the retractable transducer assembly fitted inside a forward ballast tank in the M.V. Pandora II.

In June, 1978, the assembly was installed by Burrard Drydock Ltd., under the close scrutiny of the ship's officers, Wm. R. Brown, C.R. Ward and IOS engineering and hydrographic staff - talk about sidewalk superintendents! Despite this, Burrard completed the installation prior to the sailing date and initial tests were conducted in Saanich Inlet during which no vibration or self-aeration problems were detected. So much for calm-sea trials.

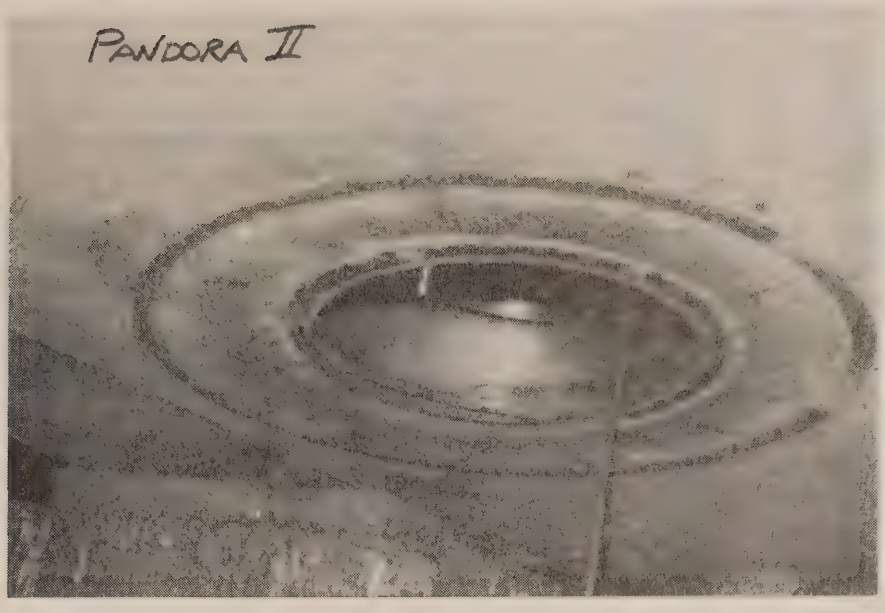


Figure 7. Opening in the hull to accommodate retractable transducer.

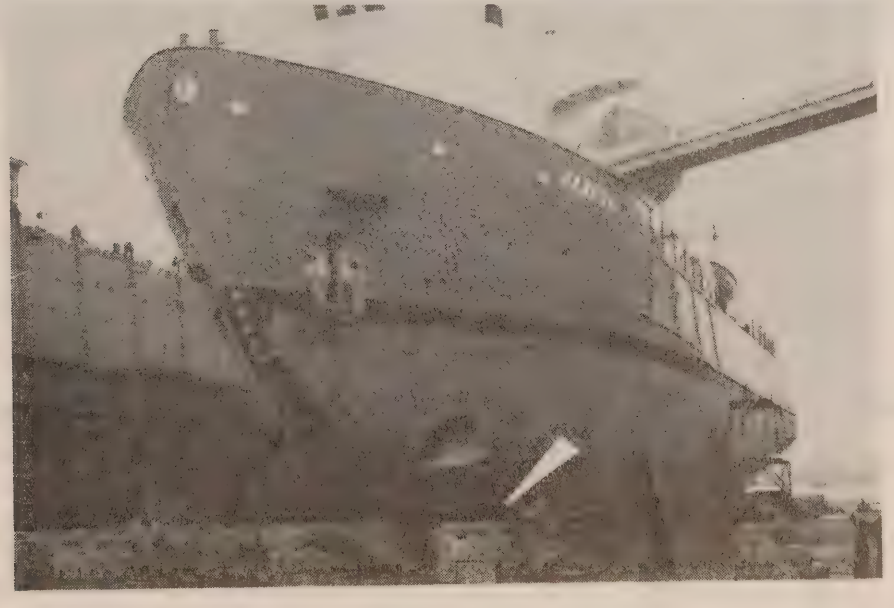


Figure 8. The M.V. Pandora II in drydock in Burrard's for fitting of the 50 cm gate valve (light spot on the port bow, aft of the bow thruster indicates location of retractable transducer).

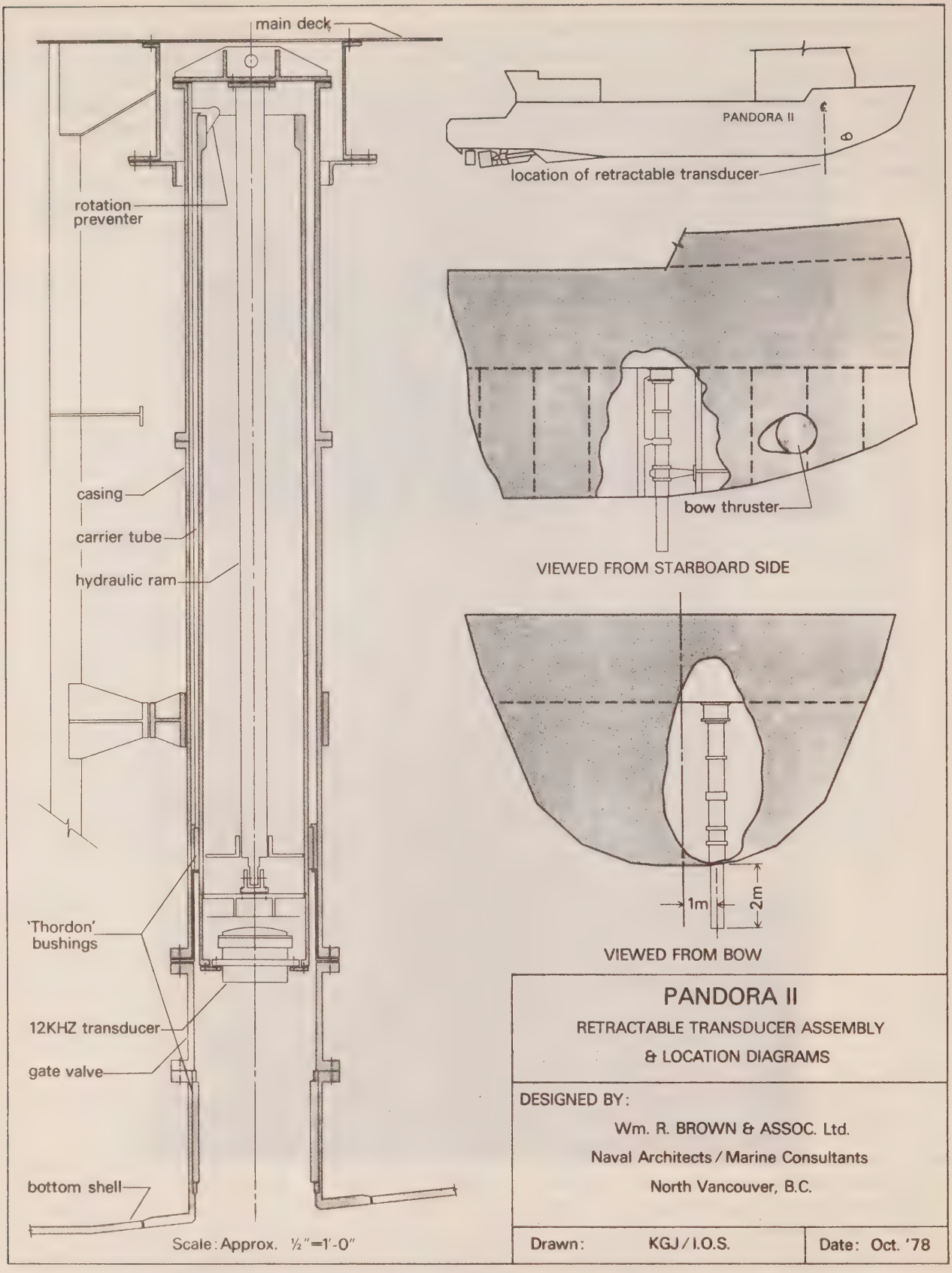


Figure 9. Retractable Transducer Assembly.

Field Results

The real test, heavy-weather operations, was to come while at sea with the ship and field staff committed to conduct a very costly survey operation in the Canadian western Arctic. The following exerpts from a brief, unpublished report prepared during Arctic operations by the Hydrographer-in-Charge, A.D. O'Connor, provide sufficient indication of the results achieved by the retractable transducer.

"July 1 found Pandora II 'rolling and pitching moderately' with the wind from the North at 25 to 30 knots, on a westerly course across the Pacific. Soundings from the hull-mounted transducers quickly became unacceptable. The ram-mounted transducer was extended to a position 0.3 metres below the hull with a remarkable improvement in sounder performance. As the sea state and swell increased, the transducer was extended to 1.2 metres and gave excellent results in depths of 3000 metres. For the remainder of the passage the ram extension was adjusted to give maximum results with minimum extension.

At midnight on August 10 (Amundsen Gulf), Pandora II was 'corkscrewing heavily' in a 10-foot sea, with the wind from the WNW at 45 knots, the ram was at 1 metre, the depth was 374 metres, and the transducer was unaffected by aeration."

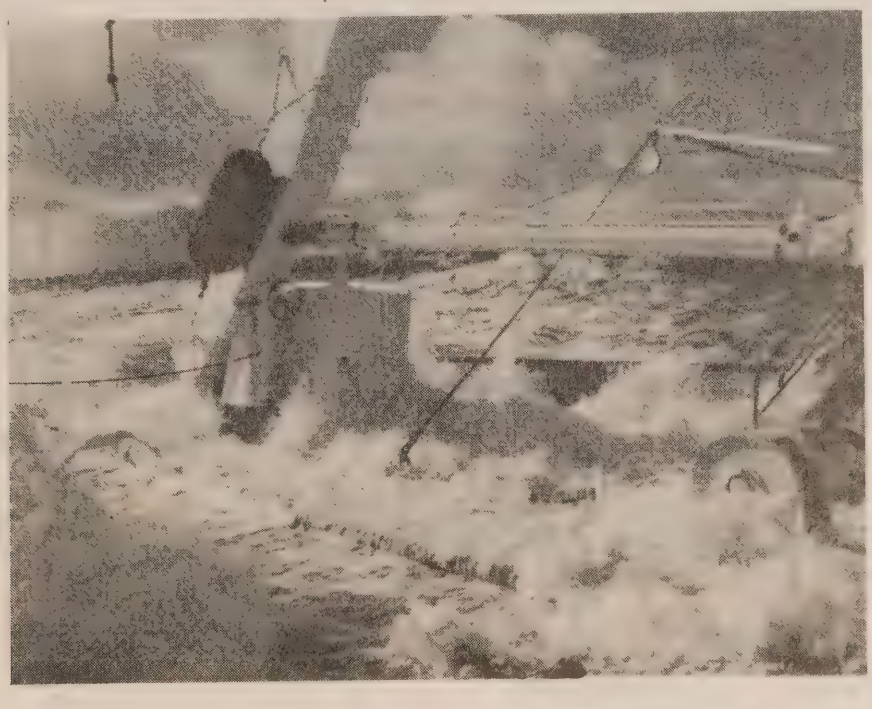


Figure 10. M.V. Pandora II, stern awash, running survey lines in Amundsen Gulf, 1978.

"The good luck, in the form of good weather, which we enjoyed last year, has deserted us. The ram is enabling us to survey in weather that otherwise could have caused 1978 to be labelled a disastrous year for western Arctic surveys."

The 'RAM' as the retractable transducer assembly has come to be designated, proved effective in operations under all conditions encountered during the 1978 Western Arctic Cruise. There was no evidence of vibration, self-aeration or self-noise problems even during violent storm conditions such as exist at sea state six. The RAM was retracted and the gate valve was closed during the passage through heavy ice near Point Barrow, Alaska. At all times when operating in the survey area the RAM was retracted when ice was encountered. There was no apparent degradation in the ship's capabilities in ice nor any problem associated with ice pressure on the gate valve. During the final leg of the journey, homeward bound across the North Pacific, acceptable results were recorded at depths in excess of 6500 metres. These measurements were obtained under the severe constraints of a very lightened ship steaming at 12 knots, often in 5 metre, following seas.

During the 1978 Western Arctic Cruise approximately 35 days of heavy weather were encountered which would have been non-productive had the retractable transducer not been available. Considering total daily operational costs in excess of $10,000, the above statistic indicates that the capital investment in this modification was recovered early in the first season of operation.

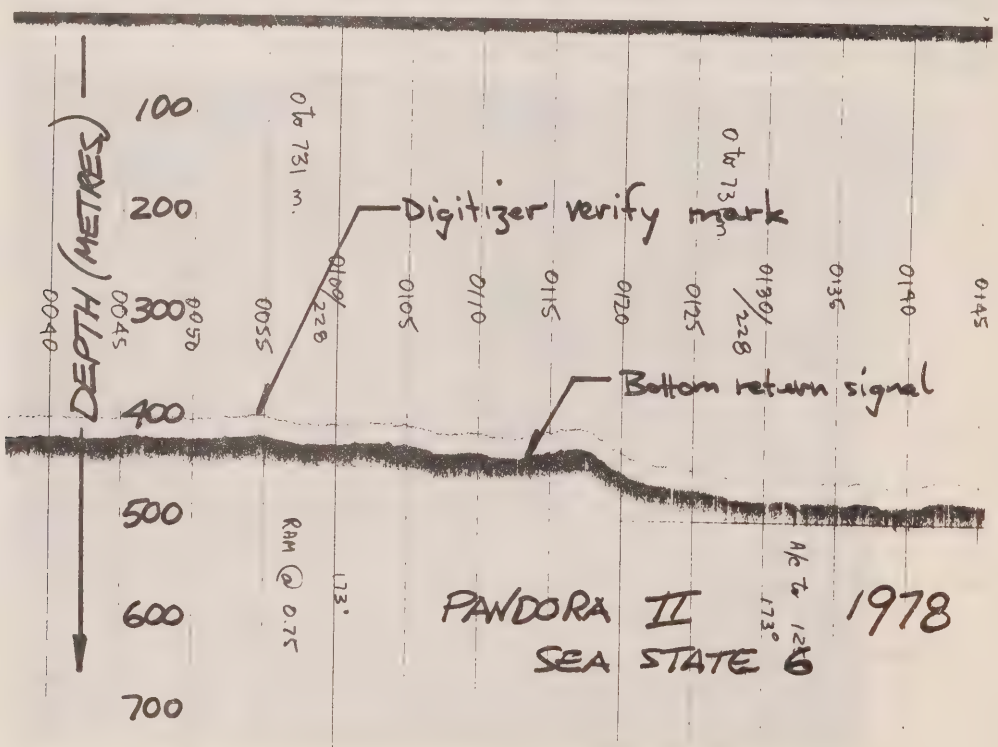


Figure 11. A sample of the greatly improved quality of echograms recorded during sea state 6 (5 to 5.5 metre wave heights) with the extendible transducer at 0.75 metres. The wind was NW at Force 10.

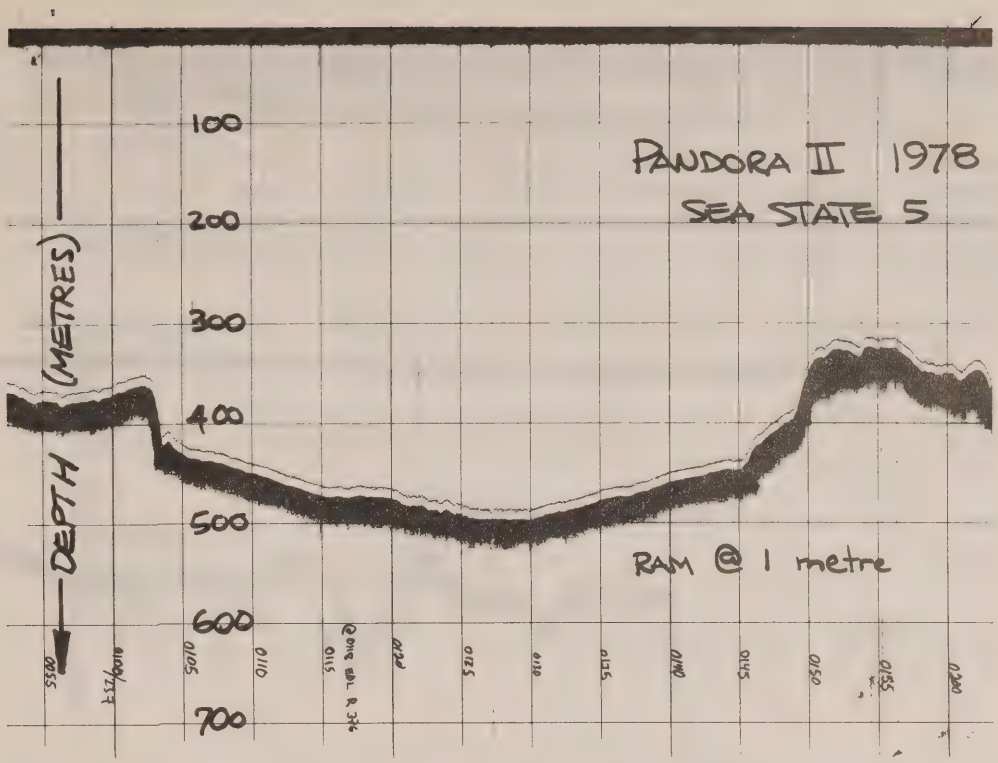


Figure 12. Echogram sample recorded during sea state 5, winds Force 7 conditions, a roll of 33° was registered while running this line. The transducer was extended to 1 metre.

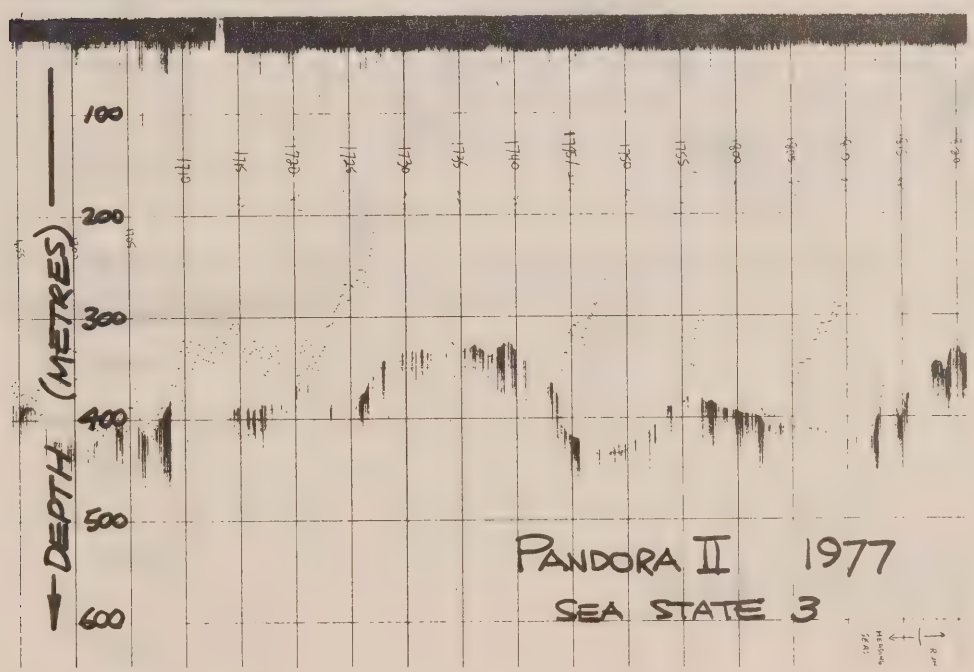


Figure 13. Duplicate of Figure 4 repeated for ease of comparison with Figure 12.

Conclusions

The extendible transducer recently fitted aboard the M.V. Pandora II successfully avoids the serious aeration problem which had frustrated attempts to conduct bathymetric surveys under all but the most favourable sea conditions. Already a good return on this investment has been realized in terms of increased productivity during the 1978 Western Arctic Survey. We won one!

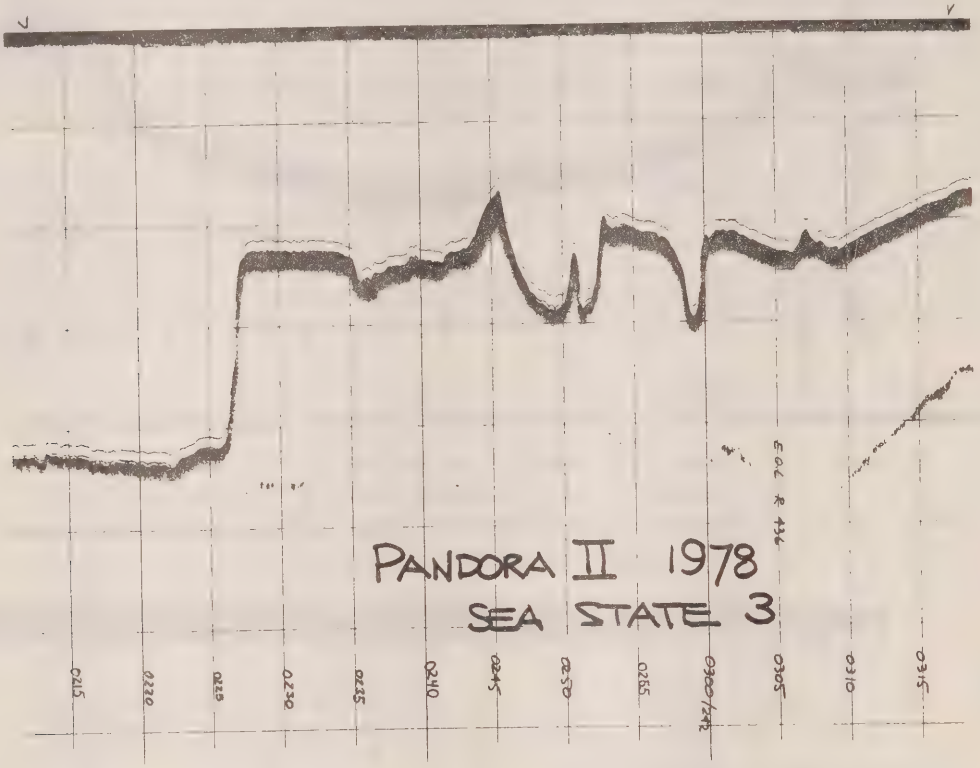


Figure 14. Echogram sample recorded with ship operating in slight seas with a 0.5 metre transducer extension.

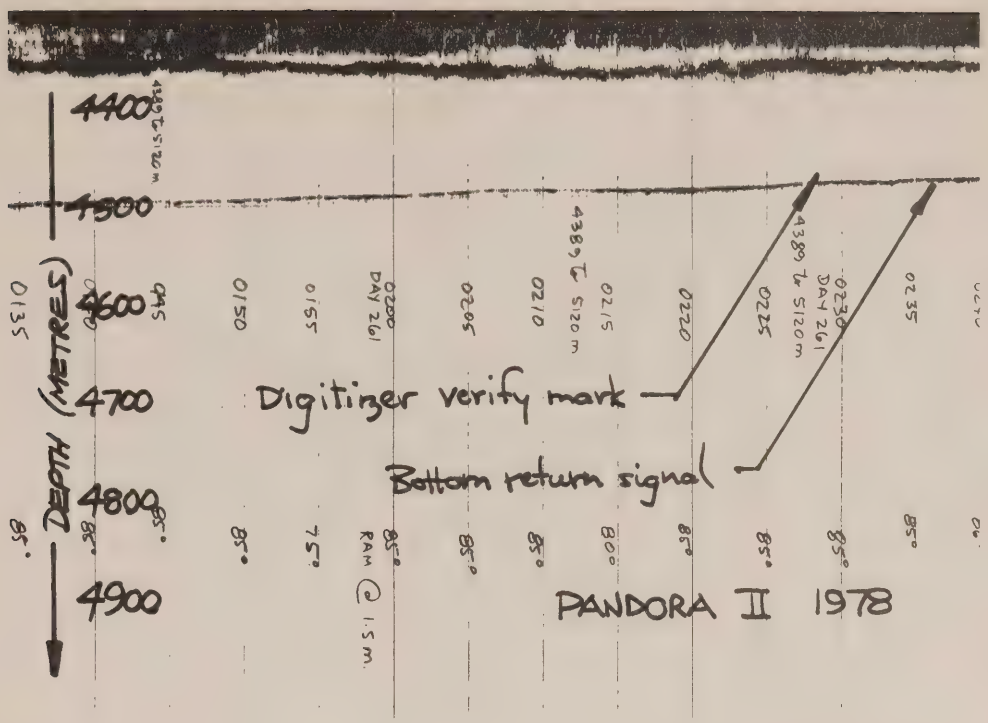


Figure 15. Echogram sample recorded in 4500 metres in the North Pacific.

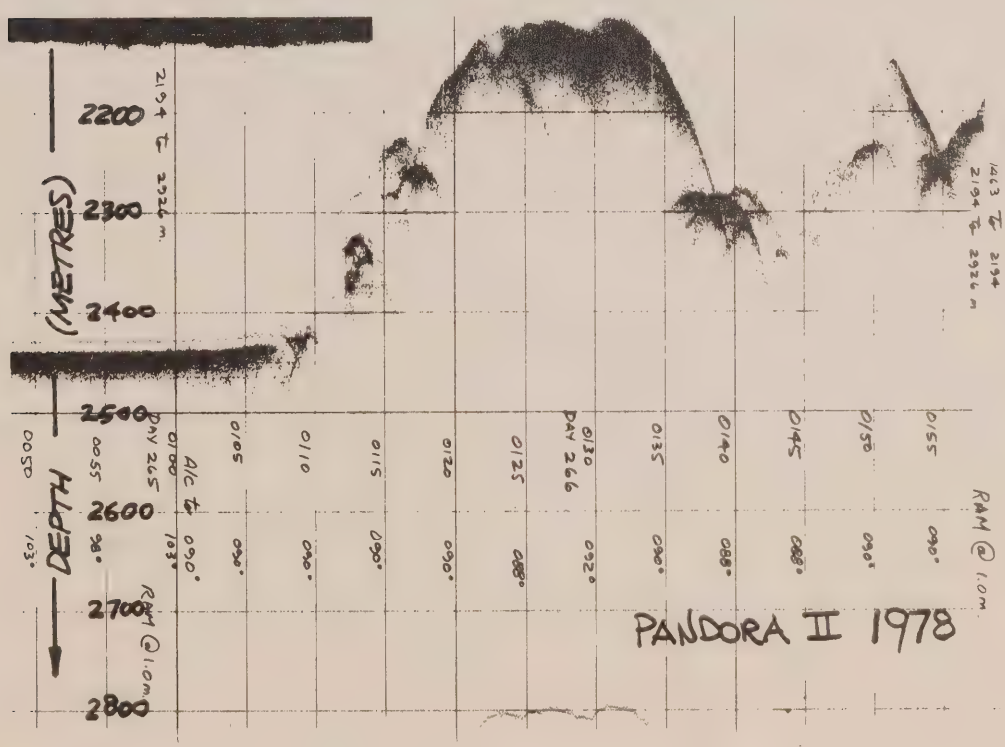


Figure 16. Echogram sample recorded as ship approached the continental shelf in 2400 metres.

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A GUIDE TO THE EFFECTS OF UNDERWATER SHOCK WAVES ON ARCTIC MARINE MAMMALS AND FISH

by

S.H. Hill



INSTITUTE OF OCEAN SCIENCES, PATRICIA BAY
Sidney, B.C.
1978

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This is a manuscript which has received only limited circulation. On citing this report in a bibliography the title should be followed by the words "UNPUBLISHED MANUSCRIPT" which is in accordance with accepted bibliographic custom.

ABSTRACT

A simple method is given for the calculation of safe distances and/or lethal ranges from underwater explosions for fish and marine mammals.

The physical properties of underwater shock waves are outlined, and some commonly-used sources (explosives, air-guns) are described. Their effects on fishes and marine mammals are discussed, and various methods for the prediction of damage to fish and mammals from underwater shock waves are described and tested against published results. The general anatomy of marine mammals is discussed and, together with the results of experiments on land mammals, is used to assess the vulnerability of such animals to underwater shock-wave damage.

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INTRODUCTION.

This report investigates underwater shock waves and their possible effects on Arctic marine mammals and fish. It is totally based on a survey of relevant literature; no laboratory experiments were carried out.

During the past decade, a phenomenal growth in interest in Canada's North has been shown by industry, science and the general public. Much of this interest has been directed toward the possibility of finding large deposits of oil and natural gas and, to this end, the oil industry is involved in extensive, on-going, geophysical exploration of the Arctic. Geophysicists use seismic surveying techniques to locate rock formations which may hold oil and gas. When seismic surveys are carried out at sea, which is often the case in the Arctic, sources of high-intensity sound, such as explosives and air-guns, are placed directly in the water. Damage to marine mammals and fish from such underwater sound sources has been a concern of northern residents - particularly hunters and fishermen - and of Government managers faced with the problem of drawing up meaningful, environmentally-sound regulations governing the use of seismic sound sources.

The objectives of this report are threefold : to describe the properties of underwater shock waves; to describe the damage caused to living organisms by underwater shock waves, identifying causes where possible; and to find a rational, simple means of predicting the extent of such damage to marine mammals and fish. To simplify presentation, the report has been divided into two sections : Section I presents the best damage prediction method found in the literature, together with several examples illustrating the use of the method; in Section II, all three objectives outlined above are covered in detail. Readers wishing to make damage predictions, trusting in my choice of method, are directed to Section I; those wishing to learn more about the topic and to discover the rationale behind the choice of damage prediction method should read Section II.

SECTION I.

Damage Zone Prediction Using Shock Wave Impulse

Yelverton *et al.* (1973, 1975) developed a method for the prediction of safe distances and lethal ranges for fish and mammals from underwater explosions, using the impulse of the shock wave as the determining factor. The impulse levels causing varying degrees of damage to mammals are given in Table A. Since these values were determined using relatively small (5 - 40 kg) land mammals as subjects, they probably include a 'built-in' safety factor when used to predict damage to the typically large marine mammals of the Arctic. Extensive investigations into the effects of underwater explosions on fish have shown that small fish are damaged by lower impulse levels than are larger fish. Thus, Figure A shows the impulse levels causing 50%, 1% and 0% mortality as a function of fish weight.

TABLE A : Underwater Blast Criteria for Mammals Diving Beneath the Water Surface (from : Yelverton *et al.*, 1973).

Impulse, bar-msec	Criteria
2.76	No mortality. High incidence of moderately severe blast injuries, including eardrum rupture. Animals should recover on their own.
1.38	High incidence of slight blast injuries, including eardrum rupture. Animals would recover on their own.
0.69	Low incidence of trivial blast injuries. No eardrum ruptures.
0.34	Safe level. No injuries.

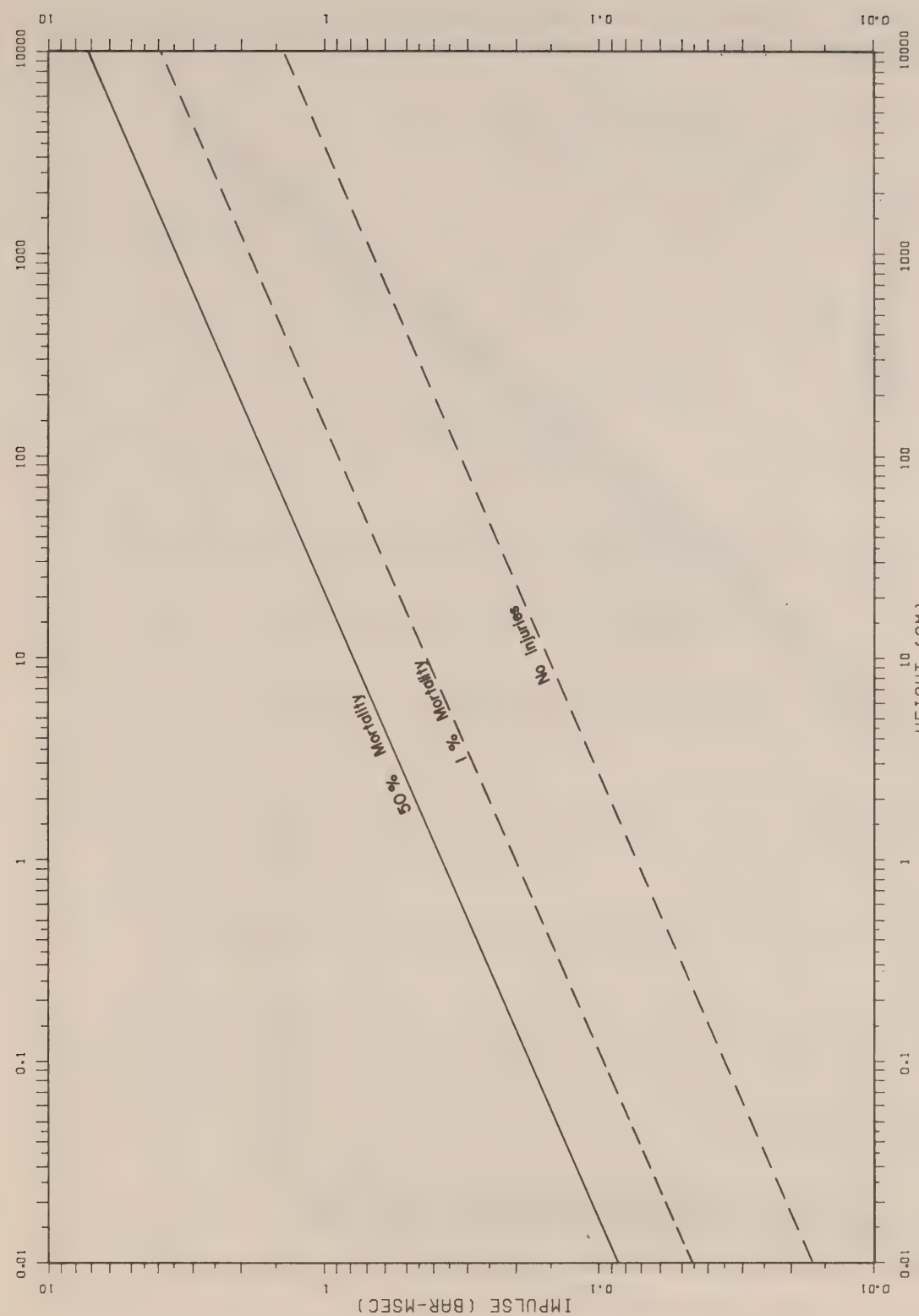


Figure A. Lethal Impulse vs Weight for Fish. (after Yelverton *et al.*, 1975).

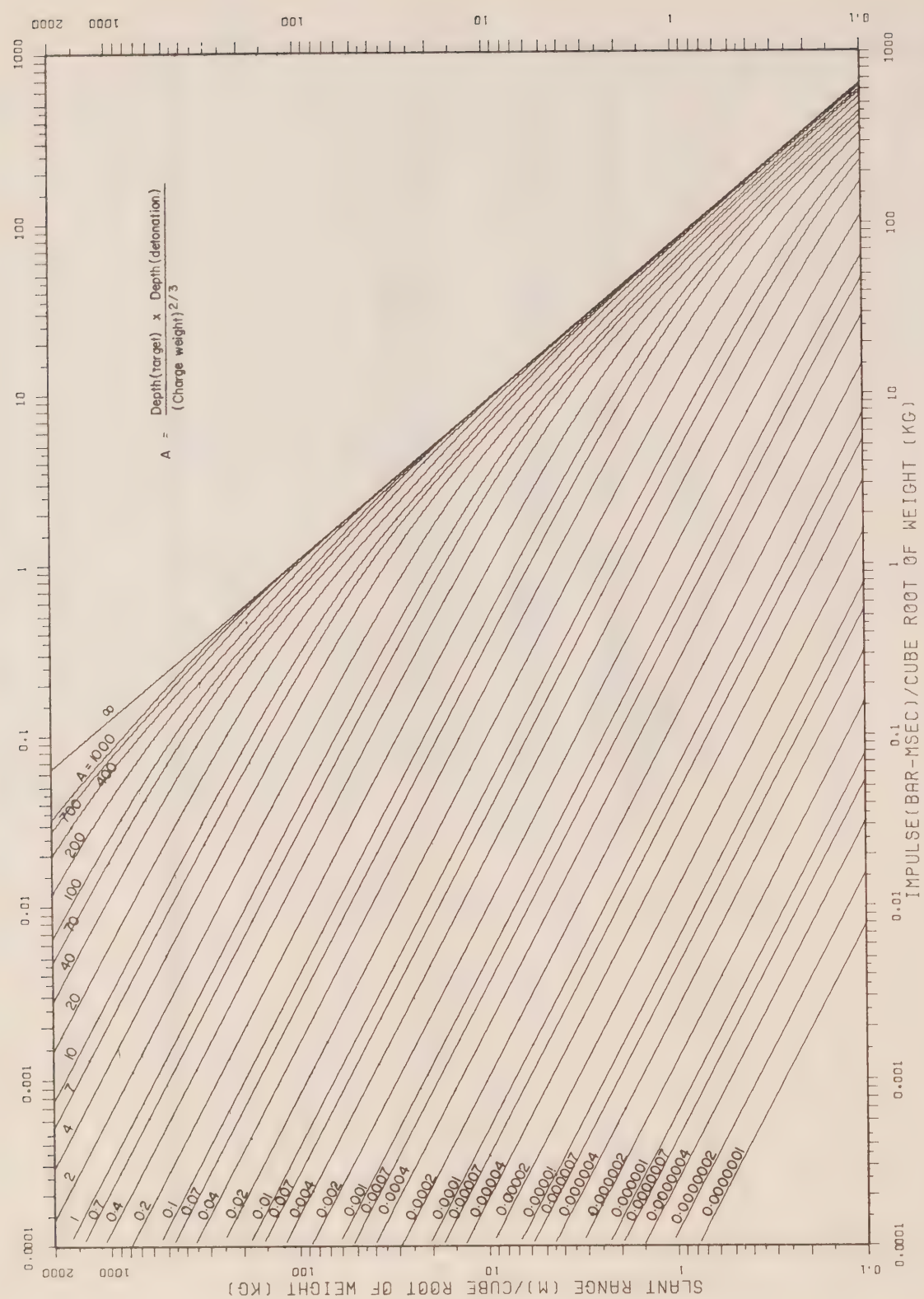


Figure B. Curves for calculating lethal ranges from impulse. (after Yelverton *et al.*, 1975).

Figure B shows the relationship between scaled impulse and scaled slant range for many values of a parameter 'A', which is derived from the depth of detonation, the depth of the target fish or marine mammal, and the charge weight, such that

$$A = \frac{\text{target depth (m) x detonation depth (m)}}{[\text{charge weight (kg)}]^{2/3}}$$

Using this method, the information required to determine lethal ranges or safe distances is :

(a) typical size of the species likely to be in the area (for fish only);

(b) depth of the target fish or mammals;

(c) depth of charge detonation; and

(d) weight of the charge.

To determine the slant range, the following steps are required :

(1) From Table A (for mammals) or Figure A (for fish) - determine the impulse corresponding to the assumed damage level;

(2) Calculate the scaled impulse by dividing the impulse found in step (1) by the cube root of the charge weight;

(3) Calculate the quantity 'A';

(4) In Figure B, find the best-fit curve to the calculated value of 'A'. Use this curve to find the value of scaled range corresponding to the scaled impulse;

(5) Calculate the true slant range (in metres) by multiplying the scaled range by the cube root of the charge weight.

This method has been tested against field results collected under a variety of conditions and has been found to work reasonably well. However, the method will underestimate lethal ranges if the water depth is shallow (less than five times either the detonation depth or target depth, whichever is greater), and the bottom is rocky. In cases like this, there may be a considerable bottom-reflected shock wave which will increase the impulse at any point. If the charge is to be detonated under thick ice, a positive rather than negative surface-reflected wave may result. Once again, this increases the impulse and, in turn, the lethal range. Under these conditions, the calculated lethal ranges or safe distances should be doubled to ensure a conservative safety margin.

EXAMPLES :

(a) What is the lethal range from a 25 kg charge for 250-gm boreal smelt (a common fish species of the coastal Beaufort Sea)? The charge is to be detonated at 3.5 m, and the smelt are assumed to be concentrated at depths shallower than 20 m.

1. According to Figure A, an impulse of 2.2 bar-msec causes 50% mortality to 250-gm fish;

2. The scaled impulse is calculated :

$$2.2/25^{1/3} = 0.75;$$

3. The quantity 'A' is calculated, using a target depth of 20 m. (This is worst case, since fish at shallower depths will experience a lower, less damaging impulse.) Then

$$A = 20 \times 3.5/25^{2/3} = 8.19$$

Thus, we use the curve for A = 7.0 in Figure B;

4. Using the curve for A = 7 in Figure B, we find the scaled range corresponding to a scaled impulse of 0.75 to be 50. The lethal range is given by

$$R_L = 50 \times 25^{1/3} = 146 \text{ m.}$$

Thus, 50% of all 250-gm smelt at depths to 20 m and within 146 m of the explosion will be killed outright.
Note that 146 m is a *slant* range - the horizontal range can be found from

$$\text{Horizontal range} = \sqrt{(\text{slant range})^2 - (\text{target depth} - \text{detonation depth})^2}$$

In this case, the horizontal range is found to be 145.0 m. Unless the target depth and detonation depth are very different, the horizontal range and the slant range are usually about the same.

(b) What is the safe distance from a 5 kg charge detonated at a depth of 5 m for ringed seals? We wish to ensure that *no harm* is done to these animals by the explosion.
Noting that the seals are feeding on small crustacea, and assuming that these are concentrated at depths less than 25 m, we can calculate the safe distance as follows :

1. According to Table A, 0.34 bar-msec is a completely safe impulse level for submerged mammals;

2. The scaled impulse is calculated :

$$0.34/5^{1/3} = 0.2;$$

3. The quantity 'A' is calculated :

$$A = (5 \times 25)/5^{2/3} = 42.7$$

Then we use the curve for A = 40 in Figure B;

4. Using the curve for A = 40 in Figure B, we find that a scaled range of 210 corresponds to a scaled impulse of 0.2. Therefore, the safe distance is given by

$$R_s = 210 \times 5^{1/3} = 359 \text{ m}$$

Provided the charge is detonated at least 359 m from the seals, there should be no risk of damage.

SECTION II.

1. INTRODUCTION.

In this Section, the physical properties of underwater shock waves are described, and their damaging effects on living organisms are summarized. Reports of scientific investigations into shock-wave damage to fish and mammals are discussed, and several methods used to predict damage are described and evaluated.

The literature on underwater blast and its effects on human and animal subjects was reviewed by Wolf (1970) and Schmidt (1973). More specifically, the literature on underwater explosions, as used in seismic exploration, and their effects on fish has been reviewed by Falk and Lawrence (1973). Some of the literature summarized in these reviews is re-examined in this report.

2. UNDERWATER SHOCK WAVES.

Underwater shock waves are compressional waves having almost instantaneous rise time to a very high peak pressure, followed by a rapid decay to ambient (or more usually below ambient) hydrostatic pressure. They are different from low intensity sound waves in that peak pressures are so high that significant changes in water density occur with the passage of the wave (density changes caused by low intensity sound waves are assumed to be infinitesimally small). Large gradients of pressure, temperature and density exist from the "front" to the "rear" of the wave, and much of the energy of the wave is dissipated as heat.

Underwater shock waves are created naturally by earthquakes, or artifically by explosive processes. Such man-made shock waves are used by geophysicists in seismic exploration and by scientists in acoustic research, and are created incidental to underwater blasting and demolition. Shock-wave-producing explosions may also be used for various purposes by the military.

2.1 Underwater explosions as sources of shock waves

The best known and most commonly used sources of underwater shock waves have been chemical explosives. The theory of underwater explosions is treated by Cole (1948), and the properties of explosives as sources of underwater sound have been reviewed by Weston (1960, 1962). An excellent step-by-step description of underwater explosion processes is given in a booklet prepared by the United Geophysical Corporation (Kramer *et al.*, 1968). The following summarizes information from these references.

2.1.1 Production of the shock wave

The explosives best suited to creating powerful underwater shock waves are the detonating-type or "high" explosives. In these explosives, the transformation of explosive material to gas occurs so rapidly that it keeps pace with the physical disturbance resulting from the reaction. Within the explosive, this results in a very narrow, steep-fronted detonation wave, in front of which is unreacted explosive substance, and behind which are the product-gases at extremely high temperature and pressure. The speed at which the detonation wave passes through the material is a characteristic of the explosive - for TNT it is roughly 6600 m/sec. Gas pressures just behind the wave may be greater than 140 kilobars (1.38×10^5 atmospheres), and gas particles there will have a net outward speed of approximately 1800 m/sec (Cole, 1948). When all the explosive has been consumed, the detonation wave arrives at the gas-water interface. The high pressure detonation wave is then transformed into both a high-intensity pressure wave - shock wave - in the water, and an outward flow of water. The bubble of product gases then begins to expand, and pressure at the gas-water interface drops rapidly.

2.1.2 Properties of shock waves in water

The shock wave, created as the detonation wave meets the water, propagates rapidly outward, having the form of a nearly instantaneous rise to maximum pressure, followed by an exponential pressure decrease with a time constant measured in microseconds (see Figure 1). This wave is of such high intensity that much of its energy is quickly lost through the production of heat; these losses combined with spherical divergence cause the peak pressure to drop rapidly as the wave propagates outward. For a spherical charge of TNT, the peak pressure of the shock wave drops from 69 kbar at a range of 1 charge radius to 1.1 kbar at a range of 10 charge radii. The propagation-speed of the shock wave also varies directly with the pressure (and thus the density) of the water, so that the shock wave's speed changes from 4270 m/sec at range (R) = 1 charge radius to 1650 m/sec at R = 10 charge radii (Kramer *et al.*, 1968). By comparison, the speed of low intensity sound waves in seawater is roughly 1490 m/sec. Another effect of the very high peak pressures in the region of the charge is to increase the duration of the wave as it travels outward from the charge. The time constant (t_o) of

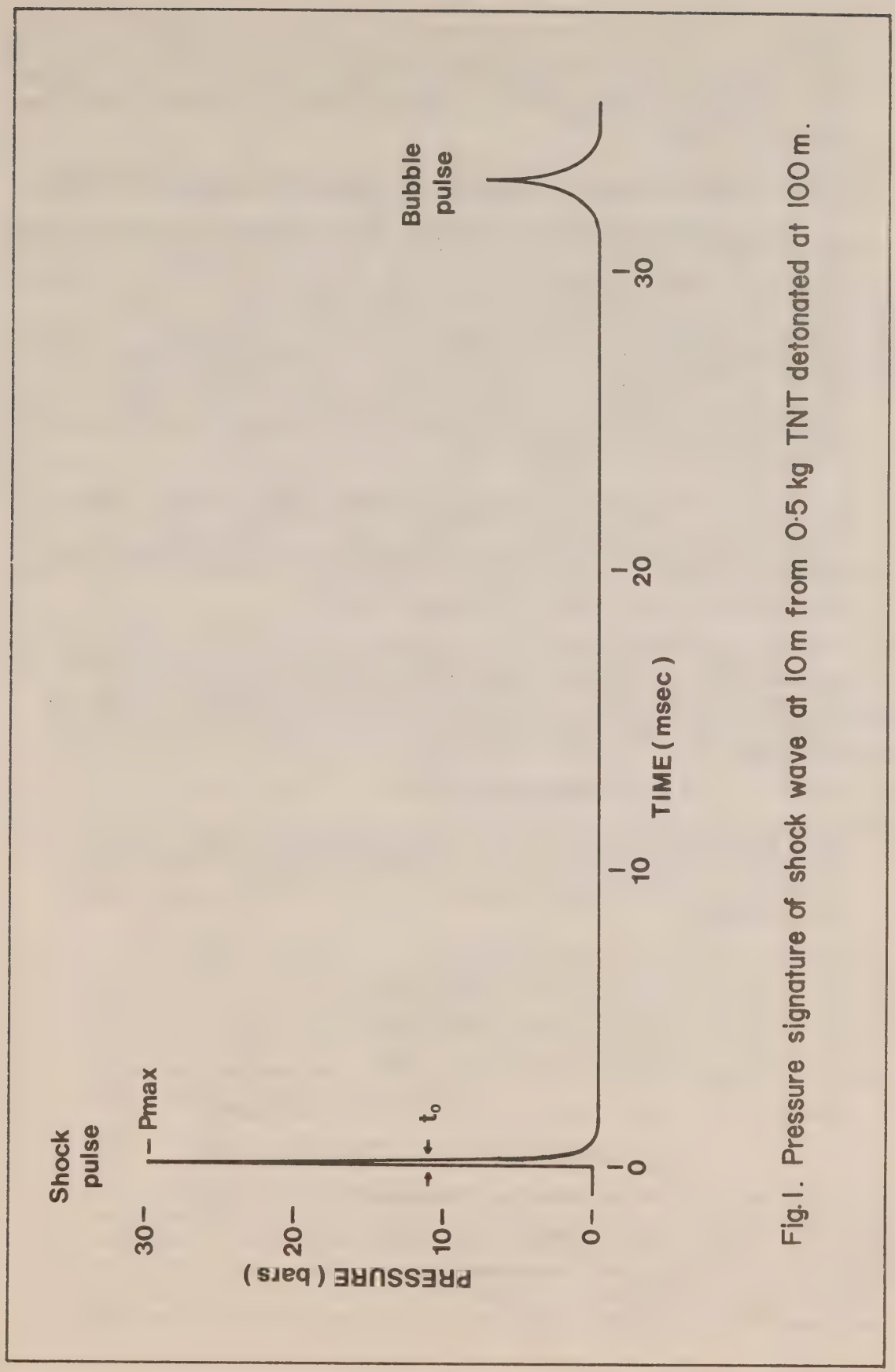


Fig. 1. Pressure signature of shock wave at 10 m from 0·5 kg TNT detonated at 100 m.

exponential decay of pressure increases to tens or hundreds of microseconds at distances beyond about 10 charge radii; (e.g. for a 2.25 kg charge of TNT, t_o = 208 μsec at a range of 15 m). This "broadening" continues as the wave propagates outward, but more slowly than near the charge.

2.1.3 Empirical Equations for Shock Waves from Spherical Charges

For the purposes of this report, we can ignore the region close to the charge (ranges less than 10 charge radii), because conditions there are almost certain to be lethal to any living thing. Beyond this range, low-amplitude acoustic approximations still do not satisfactorily describe the properties of the shock wave. Because the mathematical theory of shock waves is exceedingly complex, empirical relations are used to predict the characteristics of shock waves generated by spherical explosives. These relations are based on physical measurements and on the Principle of Similarity (Cole, 1948), which states that :

". . . if the linear dimensions of the charge and all other measurements are altered in the same ratio for two explosions, the shock waves formed will have the same pressures at corresponding distances scaled by this ratio if the times at which pressures are measured are also scaled by the same ratio."

For spherical charges, the linear dimensions of the charges are proportional to the cube root of the volume, which is itself directly proportional to the weight of the charge (W). Thus, if distances are made proportional to $\sqrt[3]{W}$, so that scaled distances R satisfy

$$R = \text{constant} \times W^{1/3}$$

then shock wave pressure-time curves measured at these scaled distances should be the same if plotted to reduced times $T/W^{1/3}$. The following relationships have been derived from experimental measurements :

$$P_m = k(W^{1/3}/R)^{\alpha}$$
$$I = \ell \times W^{1/3}(W^{1/3}/R)^{\beta}$$
$$E_f = m \times W^{1/3}(W^{1/3}/R)^{\Phi}$$
$$t_o = n \times W^{1/3}(W^{1/3}/R)^{\theta}$$

where k, ℓ, m, n, α, β, Φ, θ are constants,

P_m = maximum pressure (bars),

I = impulse (bar-msec),

E_f = energy flux (Joules/m^2),

t_o = time constant (μsec),

W = charge weight (kg)

R = distance to charge centre (m).

TABLE 1. Values of Constants in Empirical Equations for Shock Wave Parameters (After Cole, 1948)

Explosive type	Density (gm/$m\ell$)	Equations for : P_{max} (bars) k	α	Impulse (bar-msec) i	β	Energy flux density (Joules/m^2) $m \times 10^{-4}$	Φ	Time constant (t_o) (micro-seconds) n	θ
TNT	1.52	523.5	1.13	57.5	0.89	8.21	2.05	92.5	-0.22
Loose tetryl	0.93	509.2	1.15	62.7	0.98	9.76	2.10	?	?
Pentolite	1.60	545.3	1.13	74.0	1.05	10.44	2.12	?	?

N.B. The above relations hold only for spherical charges of the specified density, detonated in open, deep water at a depth great enough to ensure no large disturbance at the surface. They describe the derived parameters reasonably well between pressures of 1720 bars (corresponding to R = 7 charge radii), and 6.5 bars (corresponding to about 900 charge radii). For a 2.5 kg charge of TNT, these limits would correspond to 0.5 m and 64.0 m respectively.

Although the above relationships do not hold for distances beyond 900 charge radii, it would be incorrect to assume that, at these distances, acoustic approximations could be used to describe the shock wave properly. Marsh *et al.* (1965) have shown that finite amplitude effects persist at ranges far beyond 900 charge radii. This need not concern us since conditions at great ranges are probably not dangerous to living organisms.

2.1.4 Bubble Pulses and Negative Pressures

An outward flow of water is also produced when the sphere of high-pressure gas produced by the explosion impacts on the water boundary. Due to the inertia of this outflowing water, the bubble of product gases will expand beyond the point at which the pressure in the bubble is equal to the ambient hydrostatic pressure. At maximum bubble expansion, the pressure imbalance will cause the

bubble to collapse in on itself, reversing the outward flow of water to an inward flow. This causes the generation of a low-amplitude wave of negative (below ambient level) pressure. The inertia of this inward flowing water now compresses the bubble of gases beyond the hydrostatic pressure until inertial forces are overcome and the cycle begins again. At the point of minimum bubble volume, a high-pressure "bubble pulse" is produced; its peak pressure is roughly 10% of that of the initial shock wave. The shape of this pulse is much different from that of the shock wave, as can be seen in Figure 1.

A series of bubble pulses is generated, each with successively decreasing amplitude. The depth of the bubble decreases as the buoyant bubble rises toward the surface. Since hydrostatic pressure largely determines the period of bubble oscillations, the period will change as the bubble rises. Fortunately, bubble pulses have not been shown to be particularly damaging to living organisms, so that we need not consider them in any further detail. The low-amplitude negative pressure wave between the shock wave and the first bubble pulse may cause damage, and will be mentioned again.

2.1.5 Frequency Composition of Shock Waves from Explosions

The pressure-time signature of an underwater explosion consists basically of the initial high-pressure shock pulse, a low amplitude wave of negative pressure, and one or two bubble pulses (see Figure 1). Expressed in the frequency domain, the energy of this "wave train" is concentrated in a narrow band around some peak frequency - probably between 10 and 200 H_z - which depends mainly on the decay time of the shock pulse. Energy content decreases quite rapidly (roughly 6 - 12 dB/octave) above and below this peak frequency. Thus, the high frequency and very low frequency contributions to the energy of the shock wave are insignificant compared to the low frequency contribution.

2.1.6 Properties of Shock Waves Produced by Linear Charges

AQUAFLEX (TM), a form of detonating cord modified for underwater use has been used extensively in under-ice seismic exploration in the Arctic Archipelago (R. J. Koenig, Sun Oil Co., Ltd. - pers. comm.). For this reason, I made some theoretical calculations to determine the pressure distributions and pressure-time curves around this type of charge, using a method outlined in Appendix 1. Results of these calculations are shown in Figures 2 and 3. Calculations of absolute values of pressures generated are based on data from Cole (1948) for detonating cord of weight 9.8 g/m. This is very close to the value of 8.5 g/m. (40 grains/foot) which has been used most commonly in recent under-ice seismic work in the Arctic Archipelago, according to geophysicists working with the Arctic Islands Exploration Group (a consortium of petroleum exploration companies). The peak pressures around an 8 m length of charge of this strength are much higher off the sides of the charge than off the ends; pressures off the end at

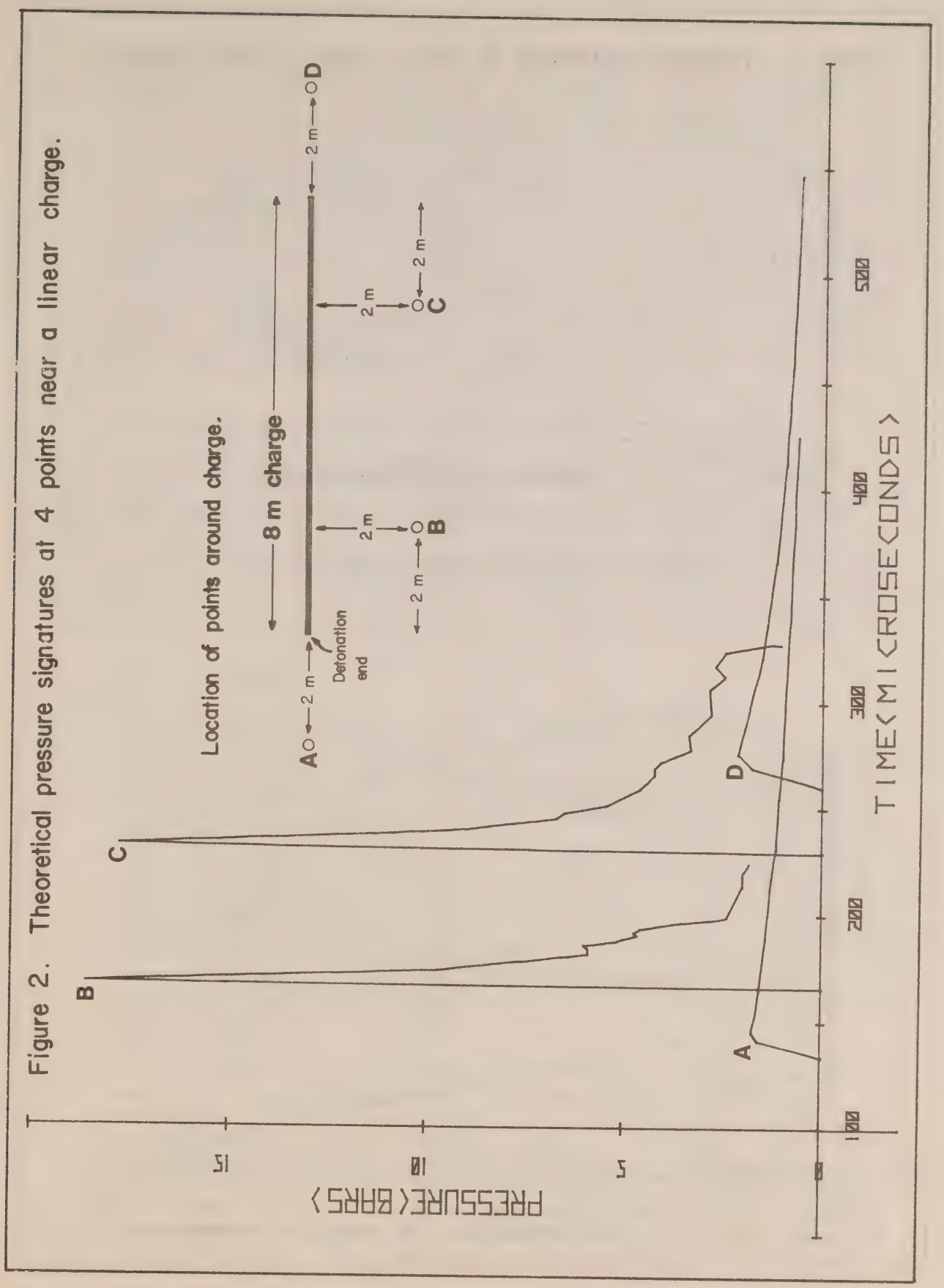
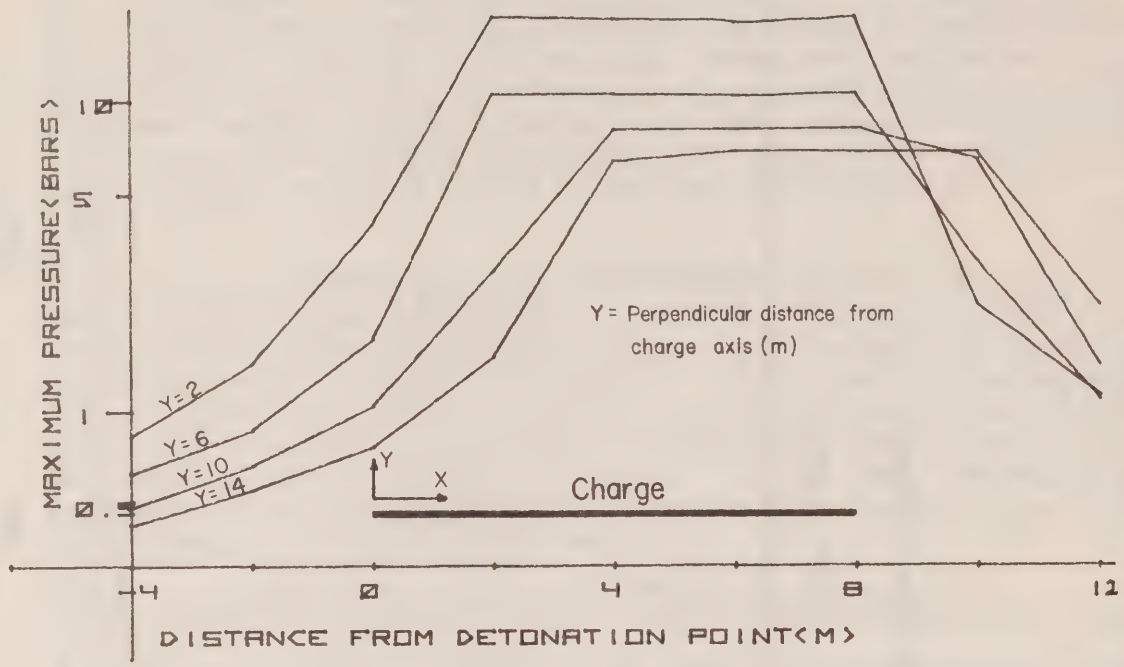
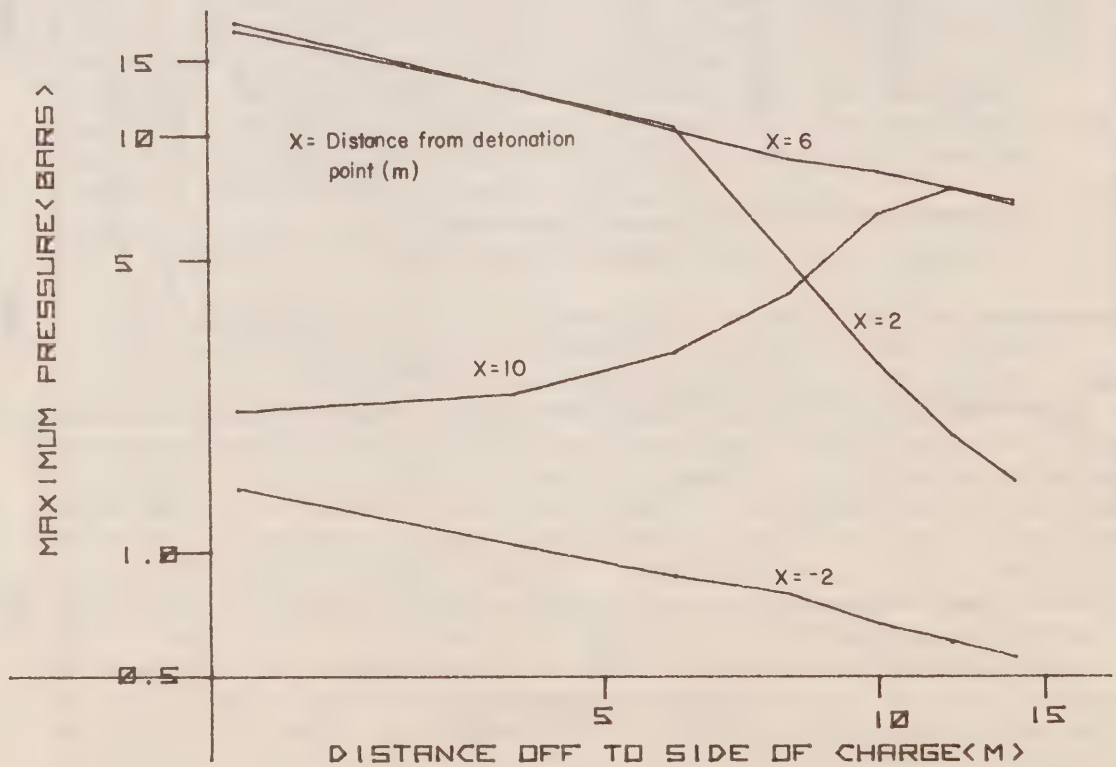


Figure 2. Theoretical pressure signatures at 4 points near a linear charge.

Figure 3. Theoretical distribution of Pmax around a linear charge.





which the detonation begins are lowest. The shock wave's time constants of pressure decay are considerably larger for Aquaflex than for an equivalent weight of point-source explosive; in addition, low over-pressures persist for relatively long times. In a direction perpendicular to the linear charge at close ranges (less than at least twice the charge length), the pressure decays as the inverse square root of the range, a situation analogous to cylindrical spreading (see section 2.3.1 below). Actual decay would be more rapid than this because of energy losses through dissipation. Maximum pressures at a given range are lower than they would be for the equivalent weight of point source explosive; for example, the pressure calculated at 6 m off to the side of a linear charge is 10.4 bars, compared to a calculated value of 18.1 bars at 6 m from the equivalent point source explosion.

2.2 Shock Wave Sources other than Explosives

Explosives have been widely used as energy sources in seismic exploration, but have many disadvantages. They are dangerous, they cannot easily be used as continuous, repetitive sources, and there are many regulations governing their use. To avoid these difficulties, geophysicists and engineers have developed a wide variety of non-explosive sources of seismic energy, all of which produce shock waves. Most of the available devices are described by Kramer *et al.* (1968) and Falk and Lawrence (1973), so that only one source - the air-gun - is discussed in detail here.

2.2.1 Air-guns

Air-guns have been used a great deal in marine seismic exploration in the Beaufort Sea and Parry Channel [John Card (Sun Oil Co., Ltd.) - pers. comm.]. Basically, the gun consists of a chamber which can be filled with high pressure air through a hose from the surface. This high-pressure air is rapidly released into the water when an electrically-operated valve is opened. Since water pressure rises very quickly from hydrostatic to the pressure of air in the gun, a steep-fronted shock wave is generated. This shock wave differs from an explosive-produced shock wave in that its peak pressure is relatively low (it must, of course, be lower than the initial pressure of the air in the gun), and both the rise time of the shock pulse and the time constant of pressure decay are comparatively long. Dissipative losses are minimal in this shock wave because of its low peak pressure.

The bubble of air released by an air-gun undergoes a series of oscillations, and produces bubble pulses similar to those from explosions. In order to attenuate these bubble pulses, which can produce spurious "ghost" images in seismic records, air-guns are usually used in arrays. Arrays typically consist of several guns of different sizes which are fired simultaneously. The initial pulses are all in phase and tend to enhance each other, but since bubble oscillation-time depends on gun volume, the bubble pulses occur at different times. Thus, the bubble pulse portion of the pressure

wave is "smeared out" and of low amplitude compared to the initial shock pulse.

Shock waves produced by single air-guns have an energy distribution in the frequency domain similar to that of shock waves from explosives, (see 2.1.5 above), except that the peak frequency is usually lower. This is a consequence of the longer rise time and decay time of the initial air-gun shock pulse. In the case of air-gun arrays, where the bubble pulse is attenuated, energy does not decrease so rapidly at frequencies below the peak. This has the effect of increasing the energy content at very low frequencies.

The total energy content of shock waves from air-guns is determined by the volume and pressure of air in the gun. A typical air-gun has a volume of 5 ℓ and is operated at a pressure of 140 bars, but gun volumes range from 17 $m\ell$ to 33 ℓ, and operating pressures range from 14 bars to 152 bars (Falk and Lawrence, 1973). The peak pressure generated by air-guns is roughly proportional to $(\text{Volume})^{0.33}$ for single guns, and to $(\text{Total Volume})^{0.85}$ for arrays (Weinhold and Weaver, 1973).

2.3 Propagation of Shock Waves in Water

2.3.1 Spreading Laws

When frictional and dissipative effects are ignored, all disturbances propagating outward in three dimensions from an underwater source diminish in intensity according to some spreading law. Consider a point source in a limitless medium (a situation physically approximated by a small quantity of explosive detonated at mid-depth in a deep ocean). The energy of the wave or pulse passing through a unit area of a hypothetical sphere at range R from the source will diminish as $1/R^2$ and the pressure will diminish as $1/R$, since pressure is proportional to the square root of the energy. This is the spherical spreading law.

Consider a point source in a layer of water confined between two infinite rigid plane boundaries (a situation physically approximated by a small quantity of explosive detonated in a shallow, flat-bottomed sea covered by a thick layer of sea ice). Assuming R to be several times the water depth, the energy per unit area will diminish with the range R as $1/R$, and the pressure will diminish as $1/\sqrt{R}$. This is the cylindrical spreading law.

2.3.2 Refraction

The paths of compressional waves in water will follow straight lines unless bent (refracted) by changes in the properties - particularly temperature and salinity - of the water. This refraction effect is usually negligible over the short distances in which shock waves are sufficiently powerful to cause damage (a few hundred metres at most), except in the case of very large explosions. For example,

a pressure wave passing through water having a uniform temperature gradient of 0.09°C/m will deviate from a straight line by only 2.13 cm over a horizontal distance of 305 m (Cole, 1948). Although situations may exist where refraction of shock waves plays an important role in defining zones of damage, refraction effects can generally be ignored - and are not discussed further in this report.

2.3.3 Reflection

Reflections of shock waves from boundaries of various types are important in determining pressure variations at a distance from the source.

2.3.3.1 Reflections from the Sea Surface

Reflections from the sea surface result in a reflected wave of negative pressure, since the pressure on the air side of the boundary is very small, requiring that the *net* water pressure at the boundary must be near zero. Some loss of energy due to scattering at the sea surface will occur, depending on sea wave heights and on the frequency composition of the shock wave. Low frequencies do not experience much energy loss at the surface, since the sea surface appears "smoother" to long wavelengths than to short wavelengths. Since shock waves are composed mainly of very low frequency energy, little surface scattering will occur. The effects of a rough surface on the reflection and scattering of various frequency components of a shock wave can be roughly determined using the Rayleigh parameter R_r :

$$R_r = kH\sin(A)$$ where

k = wave number $(2\pi/\lambda)$

H = rms wave height

A = grazing angle

for $R_r << 1.0$, the sea surface is a reflector.

for $R_r >> 1.0$, the sea surface is a scatterer.

The reflection coefficient u, where

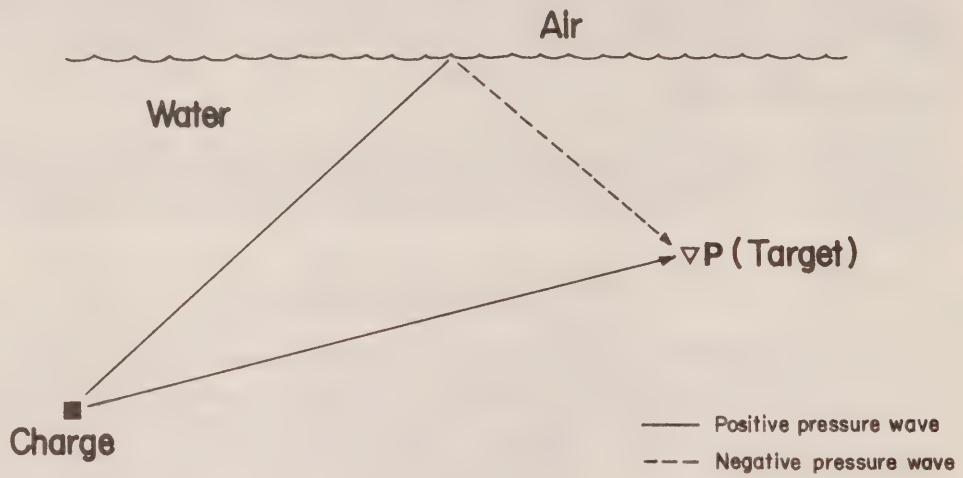
u = reflected amplitude/incident amplitude

is roughly given by

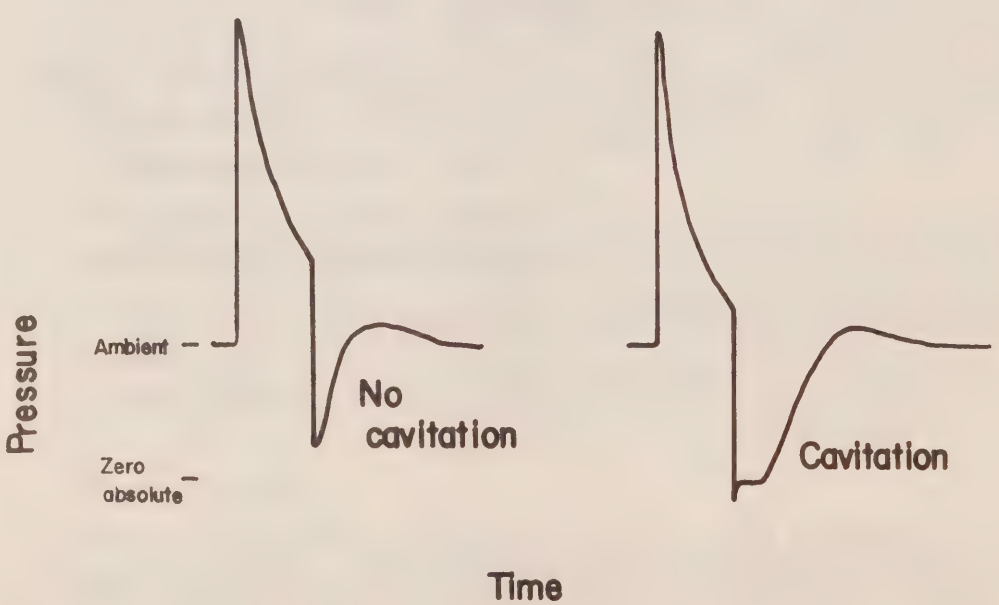
$$u = e^{-R_r}$$

Assuming that sufficient energy is reflected to result in a significantly powerful negative pressure wave at any location below the surface, the two pressures due to the direct pressure wave and the surface-reflected wave will add. The net pressure may be reduced in that location to below ambient - or even zero absolute pressure (see Figure 4). Under such conditions, the

Figure 4. Surface Reflection



Possible pressure signatures at P:



water supports a tension rather than a compression, and thus has a tendency to cavitate. Few measurements have been made to determine the amount of tension which sea-water can withstand before it begins to cavitate, but the value generally accepted in the literature is zero absolute for the onset of cavitation. Cole (1948) argues that negative pressures in sea-water are limited to less than 1 atmosphere in magnitude, since higher pressures almost certainly cause cavitation. The surface manifestation of this cavitation is the formation of the "slick" - a rapidly expanding ring of darkened water, seen if the explosive is detonated sufficiently close to the surface.

Whether or not cavitation is produced, surface reflections will reduce the shock wave's impulse (time integral of pressure) by cutting off the positive portion of the pressure-time signal. The reduction in impulse will be greatest in regions close to the surface; there the surface-reflected wave will arrive very soon after the directly-received shock wave.

The surface reflection of underwater shock waves also imparts a net vertical velocity to the surface layer of water, thus throwing it into the air. When the explosion is sufficiently close to the surface to produce a powerful reflected wave, the combination of cavitation and this vertical velocity results in the formation of a "spray dome" - a layer of broken or "shredded" water which is thrown violently into the air.

2.3.3.2 Reflections from the Sea Bottom

Reflections from the sea bottom usually produce positive pressure waves. The prediction of their properties is much more difficult than for surface-reflected waves for the following reasons :

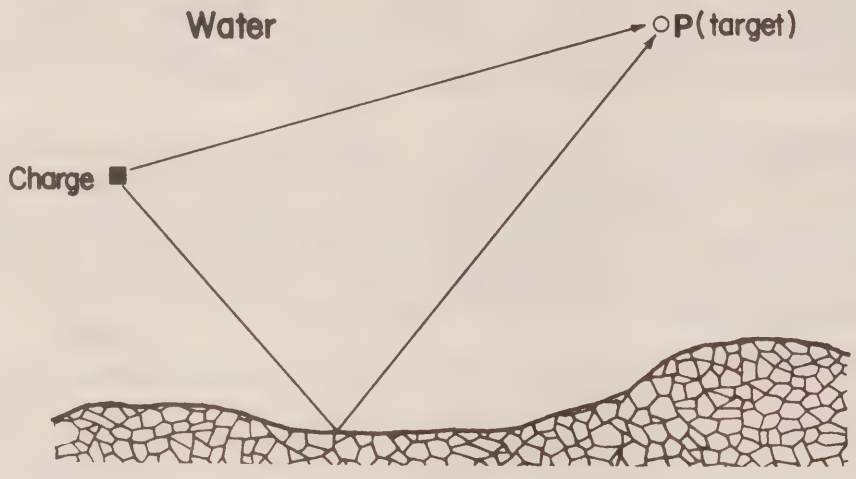
(1) significant energy can be lost due to scattering of the incident wave by a rough sea bottom;

(2) very complex reflected-wave patterns can be generated by layered bottoms of different acoustic properties (e.g. mud, sand, rock), due to variable penetration and reflection at the boundaries between successive layers;

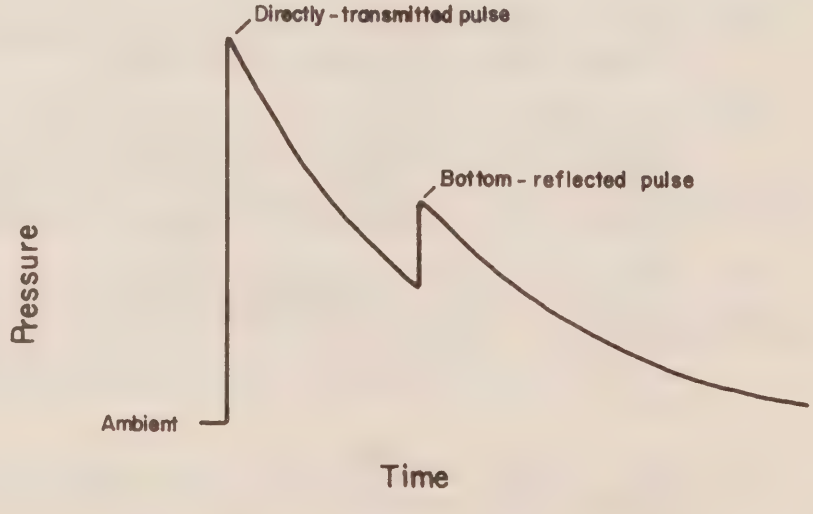
(3) the bottom material may have a sound speed gradient. The speed of sound in packed sediments increases with compaction, causing the incident wave to refract upward and re-enter the water at some distance from its entry point;

(4) muddy bottoms containing many gas bubbles (as are found in some lakes) may act as a free surface and produce a reflected wave of negative pressure.

Figure 5. Bottom Reflection



Pressure signature at P:



Theoretical calculations have been made for the simplest case - that of reflections from a plane bottom composed of homogenous marine sediments. Both the reflection and the absorption of the incident wave must be considered. The absorption loss and reflected pressure are determined by the density, sound speed, and the acoustic attenuation coefficients of the bottom sediments. Some measurements have been made to determine the values of these parameters, and some simple relationships have been found to exist. Sound speed has been found to be related to the porosity of the sediment, such that speed increases as porosity decreases. Sediment density also increases as porosity decreases, and a loose relationship exists between attenuation and porosity. These relationships have been used to compute theoretical curves showing reflection losses vs porosity and grazing angle, but such curves are rarely followed closely in field measurements (Urick, 1975). Consequently, accurate prediction of the properties of bottom-reflected pressure waves is not possible even in the simplest of cases. We will have to be satisfied with a qualitative understanding of the process which will allow us to make "order of magnitude" predictions :

- all bottom reflections will involve some absorption of the incident wave, and the amount of absorption will increase as the angle of incidence decreases;

- the amount of absorption will depend on the type of bottom material - being less for rigid non-porous materials, such as rock, than for soft, porous materials like mud;

- losses will occur due to scattering, and will depend on the roughness of the bottom.

Assuming that a reflected wave exists, its pressure will add to that received directly from the source - but at some later time. This will depend on the difference in path-length between the straight line path and the reflected wave path (see Figure 5). If the path difference is sufficiently small (i.e. the source is at or near the bottom), and if the incident wave is reflected at the bottom, the *maximum pressure* at point P could be higher than in the absence of a reflected wave. Theoretically, the pressure can be doubled if the source sits at a perfectly rigid boundary. In practice, the increased pressure may be only 10% greater than that from the directly propagated wave alone (Cole, 1948).

2.3.3.3 Reflections from Sea Ice

Reflection of pressure waves from an ice/water boundary must be considered in Arctic seas. Under-ice reflections will be governed by many of the same considerations as were involved in bottom reflections. However, variations in density and sound speed are not as great. Some of the energy of an intense shock wave may be lost in the deformation and cracking of the ice-layer

and in the production of ice flexural waves. The amount of this energy loss depends on ice thickness, the energy of the source and its proximity to the ice layer.

The underside of the ice may not be as rugged and jumbled as the seabottom, except perhaps in areas of extensive pressure-ridge formation in pack ice. On a smaller scale, the bottom of a growing ice sheet consists of a 1 to 2 cm-thick layer of ice crystals projecting vertically into the sea water. This region has acoustic properties intermediate between sea water and ice, and thus forms an excellent couple between the two media - allowing a significant fraction of incident energy to pass through the boundary into the ice.

Several measurements of reflection and attenuation coefficients for sea ice are available. Unfortunately, all of these measurements have been made using low-amplitude sound waves rather than shock waves. Nevertheless, such measurements provide a useful approximation to the behaviour of shock waves. Verrall and Ganton (1977) measured the reflection coefficients for low amplitude sound pulses (200 H_z to 20 kH_z) striking a relatively smooth ice surface. They found that reflectivity was usually less than unity for all angles of incidence tested. Langleben and Pounder (1970) also measured the amplitude coefficient of reflection of low amplitude sound pulses (20kH_z to 450 kH_z) from sea ice at different angles of incidence. They found that, although reflectivity varied significantly with frequency, in general the reflection coefficient increased with the angle of incidence from approximately 0.1 at an angle of incidence of 30°, to approximately 0.8 at an angle of incidence of 75°. For angles less than 30°, reflectivity was roughly constant at 0.1. Thus 20% to 90% of the incident intensity is absorbed at the ice/water boundary. Low amplitude sound pulses passing into the ice in this manner are attenuated rapidly. Langleben and Pounder (1970) also measured attenuation coefficients in ice and report that attenuation increases with increasing frequency, and is higher for first-year ice than for second-year ice. From 10 to 50 kH_z, the attenuation coefficients ranged from 1 to 5 dB/m.

Coefficients of reflection for *shock waves* from ice/water boundaries are probably lower than those for low-level sound pulses because some of the intensity of shock waves can be absorbed in ice deformation and in the production of ice flexural waves. Attenuation of shock waves in ice will certainly be greater than for acoustic pulses because of dissipation effects.

3. EFFECTS OF SHOCK WAVES ON LIVING ORGANISMS.

Underwater shock waves, having extremely high peak pressures and rapid rates of change of pressure, can cause severe damage to living organisms. The theory of underwater shock waves, propagating through and reflecting from yielding surfaces, is discussed by Cole (1948). In addition, there has been

considerable experimental work, using fish and land mammals as subjects, reported in the literature. Much of this work will be discussed below.

Events taking place during the reflection and absorption of shock waves at boundaries between two different media may cause death or damage when these boundaries are within living organisms. When a shock wave passes from tissue of one density to tissue of a different density (for example, from muscle to bone), the particle velocities imparted to these tissues will be different. If the peak pressure of the shock wave is high and the density difference between the tissues is large, resulting in a large difference in particle velocity, the two tissues may be literally torn apart.

Shock wave reflections at an interface between tissue and an air-filled cavity within a living organism can cause great damage to tissues at the interface. This situation is physically analogous to the reflection of an underwater shock wave from a water surface. If the peak pressure of the shock wave is high enough, a form of cavitation will occur within the tissue near the boundary. Tissue at this boundary will also explode into the air-space because of the high particle velocity normal to the boundary imparted by the reflecting shock wave. Pathological consequences of these two effects could be destruction of tissues, loss of integrity of the boundary, and possible haemorrhage if capillaries or blood vessels are present.

Rawlins (1953) places great importance on what he calls "water-movement injuries", which are injuries caused by the large outward water flow (after-flow) which follows the shockwave. However, afterflow velocity falls off as $1/R^4$ (Cole, 1948), ensuring that if an animal is close enough to the explosion to be damaged by afterflow, it will be even more seriously damaged by the shock wave, since peak pressure diminishes only as approximately $1/R$.

The parameters of the shock wave which have been identified as causing damage to living organisms are as follows :

(1) the peak pressure (P_{max}) of the shock wave;

(2) the impulse (I) of the shock wave, defined as

$$I = \int_0^T P(t)dt;$$

(3) the duration of the overpressure; and

(4) the energy flux density of the shock wave, defined as

$$E_f = \frac{1}{\rho_o c_o} \int [P(t)]^2 dt.$$

The relative importance of these parameters depends on the properties of the tissues involved (Clemedson and Criborn, 1955). If the natural period of oscillation of a tissue is short compared to the duration of the overpressure, then peak pressure will be the primary cause of damage. Here, the effect of the shock wave on the tissue is effectively that of a static overpressure.

If, on the other hand, the tissue's natural period is long relative to shock wave duration, then damage will be related to the impulse.

3.1 Effect on Fishes

3.1.1 Damage Sites

Tyler (1960) reports that the damage to salmon from underwater dynamite explosions is concentrated in the organs and tissues in the region of the gas bladder. Internal damage involved ruptured gas bladder, kidney, gonads and spleen; ribs were torn loose from the body wall, and there was torn adipose (fat) tissue and burst blood vessels in the body wall. The only external damage seen was usually a small patch of missing scales over the location of the gas bladder.

Most reports cite the gas bladder as the primary damage site in fish. In experiments with caged fish, Aplin (1947) found that explosions which killed fish with gas bladders often did not harm fish without gas bladders. Kearns & Boyd (1965) found that all fish species killed during underwater seismic prospecting off the British Columbia coast possessed gas bladders. Gaspin (1975) tested non gas-bladder fish under conditions lethal to many gas-bladder fish. Out of 370 non gas-bladder fish tested, only one was injured.

Sakaguchi *et al.* (1976) state that the sinus venosus, a blood sinus adjacent to the atrium of the heart, was the primary damage site in the carp (*Cyprinus carpio*) and the rockfish (*Sebasticus marmoratus*); however, the gas-bladder was the second important damage site in these fishes.

Gas bladders, found in the bony fishes, are absent in the hag-fishes, sharks, rays and their relatives. They are usually filled with gases - principally oxygen and nitrogen - but may also be filled with fat. They may be reduced in size or even lost altogether in some species - notably bottom or stream-dwelling fish. Gas bladders probably evolved from a primitive respiratory organ, but their primary function in present-day fishes is to act as a hydrostatic organ - enabling the fish to maintain neutral buoyancy. Fish can be classified into two broad groups, according to the presence or absence of a passage between the gas bladder and the alimentary canal. Those with such a connection are termed "physostomous", and those without are termed "physoclistous". The gas bladder comprises 4 to 6 per cent of the total body volume in marine fishes, and 7 to 11 per cent of the body volume in freshwater fishes (Lagler *et al.*, 1962). The difference in these two figures is ascribed to the density difference between salt and fresh water.

3.1.2 Causes of Damage.

The high peak pressures and rapid rise times of shock waves produced by high explosives are most damaging to fish. In contrast,

"black powder" explosions, typified by low peak pressures and long rise times, cause little or no damage to fish (Hubbs and Rechnitzer,1952).

Some workers (Hubbs and Rechnitzer,1952; Kearns and Boyd, 1965; Christian, 1973), note that the edges of perforations in injured gas bladders are usually turned *outward*, and that blood and fragments of the gas bladder are blown into the abdominal cavity, as if the gas bladder had exploded outward rather than inward. This strongly suggests that the negative pressure wave produced by the reflection of the shock wave at the surface is the prime cause of damage to the gas bladder. Muir (1959) investigated the effect of mechanically-produced negative pressures on Coho salmon fingerlings. He found that a sudden reduction of pressure from 8.6 bars to 0.03 bars, with no cavitation, killed few fish (about 10%). When cavitation was produced by a greater reduction of pressure, 60% of fish died.

Sakaguchi *et al.* (1976), investigating the effects of various types and amounts of explosives on fish, found that peak pressure was not a reliable indicator of damage level. However, the energy flux density (E_f) was highly correlated with damage level. The pressure signature resulting from any explosion is dependent on the type of explosive and on the conditions of the blast, such as water depth, bottom type and depth of detonation. Thus, explosions with the *same* peak pressure can have different peak pressure durations and rise times and, in turn, have very different physical effects on fish.

Yelverton *et al.*(1975) found convincing evidence that impulse is strongly related to degree of damage. For a given fish-size, the impulse causing 50 per cent mortality was nearly the same in all cases, even though the peak pressures varied widely, depending on experimental conditions.

3.1.3 Fish Sizes.

Yelverton *et al.* (1975) carried out experiments on fish, ranging in size from 0.02 gm to 800 gm, and found that the impulse causing 50 per cent mortality increased consistently with the body weight of the fish. Their regression line relating impulse causing 50 per cent mortality (I_{50} in bar-msec) to body weight (BW, in g) is the following :

$$\ln(I_{50}) = -0.9913 + 0.3201 \cdot \ln(BW)$$

3.1.4 Species Differences

Different species of fish have varying susceptibilities to underwater shock waves. As stated previously, species not possessing gas bladders are less vulnerable than those with gas bladders. However, Gaspin (1975) has shown that the presence or absence of an opening to the gut from the gas bladder makes no difference to the vulnerability of fish - these openings are so small relative to the size of the gas bladder that very little

gas can be vented through them during the passage of a shock wave.

Among fish possessing gas bladders, differences in susceptibility to damage may depend on the physical structure of the bladder. For example, in cods and spiney-rayed fishes, the gas bladder has a structure called the oval organ, in which the interior of the gas bladder is separated from a capillary-bed by a layer of epithelium only one cell thick. This delicate region is highly vulnerable to damage by rapid pressure changes.

3.1.5 Orientation of Fish

Sakaguchi *et al.* (1976) found that the orientation of the fish relative to the shock wave's direction of travel has a significant effect on the amount of damage inflicted. Fish struck from the ventral or lateral directions suffered significantly more damage than those struck from the head-on or tail-on directions.

3.1.6 Effects on Eggs and Larvae

Kostyuchenko (1973) investigated the effects of underwater shock waves on the eggs and larvae of 4 species of fish. Survival rates of eggs were strongly reduced by the effects of shock waves produced by small (50 g) charges of TNT. Damage to the eggs consisted of deformation and compression of the membrane, spiral curling of the embryo and its displacement to one of the poles of the egg, and impairment of the integrity of the vitelline membrane. There were differences in the degree of damage, depending on species; anchovy eggs were the most strongly affected, red mullet eggs the least. Larvae were less sensitive to the effects of shock waves than were eggs.

3.2 Effect on Mammals

3.2.1 Land Mammals

All experimental work reported in the available literature involves the use of various species of land mammals as subjects. The most commonly used animals have been goats, monkeys, dogs, cats, guinea pigs and, of course, rats. A few experiments have been reported using human subjects (at sub-lethal blast levels), and medical journals carried many reports of underwater blast injuries to humans during World War II. Early experimental work is reviewed by Bebb and Wright (1951), and more contemporary literature is reviewed by Wolf (1970) and Schmidt (1973).

3.2.1.1 Damage Sites

Experiments have shown that the principal damage sites in mammals are the gas-containing organs - the most seriously affected major organs being the lungs and the hollow viscera.

Lung injuries consist of the rupture of alveolar walls and lacerations of larger areas, with subsequent massive haemorrhage. Air emboli can also result when the boundaries between the alveolar spaces and adjacent capillary-beds rupture.

Damage to the viscera is mainly restricted to those portions of the lower intestine containing pockets of gas. This was clearly demonstrated by Greaves *et al.* (1943) who subjected 4 sections of rabbit intestine to an underwater shock wave; initially, one was collapsed, one filled with a saline solution, one filled with air, and one was filled with an air-and-saline solution mixture. Only the sections containing air were damaged. The most common injuries to the viscera are rupture and bruising of intestinal walls, and bleeding from the blood vessels of the walls. Gut contents can escape into the peritoneal space if the intestinal wall is perforated.

Gouze and Hayter (1944) showed that the air emboli produced by sublethal lung damage can lodge in the heart and brain, causing death by cardiac arrest or stroke. Some writers (see Schmidt, 1973) report pathological changes to the central nervous system, but it is not clear whether these are caused by direct damage to the nervous system or are side-effects of injuries to the lungs or circulatory system. Extreme blast injury can involve the fracture of extremities and violent trauma to the thoracic cage and abdominal contents (Rawlins, 1953).

3.2.1.2 Cause of Damage

Experiments using land mammals as subjects have usually been carried out with the animals at the water surface, since at least their heads must be out of the water for them to breathe. This means that the impulse of the shock wave incident on these animals is small relative to that incident on a deeply submerged animal, because the negative surface-reflected shock wave reduces the overpressure to near zero very soon after the directly-received shock wave strikes (see 2.3.3.1 above). Under these conditions, the damage parameter most mentioned in the literature has been P_{max}. Estimates of the lethal P_{max} for humans range widely from 138 bars (U.S. Navy Diving Manual) to 21-28 bars (Revelle, 1952).

Although it is clear that high P_{max} and rapid rise time is necessary to cause injury, experimental evidence indicates that it is the impulse of the shock wave which largely determines the extent of injury. Bebb and Wright (1951) cite the case of a diver subjected to two identical blasts at identical ranges, but at different depths. In the first test, at 3 m depth, there were negligible effects but, in the second test, with the diver at a depth of 15 m, there was trauma to the lungs and ears, and severe concussion. Although the P_{max} was the same in both cases, impulse was approximately 5 times greater at the greater depth.

Richmond *et al* (1966) tested the effects of air blast on mammals using a shock tube, which allowed the duration of the shock wave to be changed while keeping the P_{max} constant - thus varying only the impulse. They found that increased impulse caused greater injury. Andersen and Løken (1968) found that they could increase the degree of damage to the lungs of rats by exposing them to shock waves of increased impulse, even though P_{max} remained constant. The effects of peak pressure, energy flux density, and impulse on both surface and submerged animals were tested by Yelverton *et al* (1973). Using a breathing apparatus, animals could be submerged to a depth of up to 3.05 m. Again, their results show that the impulse is closely related to the damage level, whereas P_{max} and the energy flux density corresponding to a given degree of damage can vary by a factor of 2.

3.2.1.3 Causes of Death

The major cause of immediate death due to underwater shock waves is suffocation caused by extensive haemorrhaging into the lungs (Clark and Ward, 1943; Greaves *et al*, 1943; Cameron *et al*, 1942). Air emboli can cause death soon after sublethal lung injury. In addition, fatal circulatory failure can occur, probably as a result of the obstruction of pulmonary circulation due to lung damage combined with general system shock.

Death often occurs at some considerable time after the original injury. This usually comes about as a result of complications, such as broncho-pneumonia in damaged lungs, or peritonitis resulting from perforations of the intestinal wall.

3.2.1.4 Factors affecting Degree of Damage

Clark and Ward (1943), Greaves *et al* (1943), and others have found that larger animals are *less* subject to injury than small animals. This may be due to higher absorption of energy in the thicker body walls of larger animals. A rigid mass, either of bone or of an artificial nature, can afford some protection against shock waves. "Rib markings" - areas of bruising and haemorrhage - have been noted on the lungs of animals injured by underwater shock waves. These markings, indicating areas of greater damage, actually correspond to the spaces between the ribs, showing that the ribs protect the lungs beneath them. Greaves *et al* (1943) investigated the effectiveness of coverings of various materials in protecting rats from shock waves. They found that rigid metal suits provided the best protection, followed by dry kapok or foam-rubber coverings.

Clark and Ward (1943) found that, if the lungs of rats and cats were kept deflated during the passage of a shock wave, the animal received less damage than one whose lungs were fully inflated. Andersen and Løken (1968) report that the right lung of rats consistently receives more damage than does the left lung -

which is 21% larger. Thus large, uninflated lungs are less prone to be damaged by underwater shock waves than small, fully-inflated lungs.

3.2.2 Marine Mammals

The vulnerability of marine mammals to underwater shock waves can only be guessed at, since no reports have been found which describe experiments on animals from this group. It is certain that some marine mammals can be killed by underwater shock waves, since Fitch and Young (1948) report that California sea-lions were killed on three occasions by underwater explosions used in seismic exploration. California grey whales observed in the region of such blasts were apparently unaffected and were not even frightened away.

Considerable information about the anatomy of marine mammals is available, particularly with regard to the adaptions necessary for survival in the underwater environment. The possible effects of underwater shock waves on these animals can be inferred from the similarities and differences in anatomy between marine and land mammals.

3.2.2.1 Marine Mammals of the Canadian Arctic

The Cetacea (whales) and Pinnipedia (seals and walrus) common to the Canadian Arctic, together with some general information about each species, are listed in Tables 2 and 3.

TABLE 2.

Whales - in order of approximate abundance in the Canadian Arctic.

Name	Distribution in Canadian Arctic	Migrations	Feeding habits	Social habits	Maximum known diving depths	Maximum known dive duration	Typical length
Beluga (*Delphinapterus leucas*)	Holarctic	Migrate within Arctic; winter in Baffin Bay, Davis Strait	Toothed whale; feeds in shallows & beneath ice. Prefers fish, squid, shrimp.	Gregarious; found in groups of 20-30; herds of up to 1000, or more.	Shallow dives only.	10-15 min.	3.5 m.
Narwhal (*Monodon monoceros*)	Eastern Arctic	Migrate within Arctic	Toothed whale; feeds on fish, squid, molluscs, shrimp	Gregarious; found in herds of up to 100 and more	370 m.	?	4 m, exclusive of tusk
Bowhead Whale (*Balaena mysticetus*)	Eastern Arctic, Beaufort Sea	Migrate into Arctic from southern regions in summer	Baleen whale; feeds on amphipods and euphausiids	Solitary, or in small groups of 3 - 4	?	Typically sound for 30 min.	17.5 m.
Killer Whale (*Orcinus orca*)	Eastern Arctic, Beaufort Sea	Migrate into Arctic from southern regions in summer	Toothed whale; prefers warm-blooded prey (seals, beluga, narwhal)	Gregarious; travel and hunt in groups of 10 - 20	Shallow dives	Typically sound for 1 - 4 min.	6 m.
Northern Bottle-nose Whale (*Hyperoodon ampullatus*)	Davis Strait	Migrate into Arctic in summer	Toothed whale; feeds on Arctic squid	Gregarious; travel in groups of 4 - 10.	800 m	2 hr.	7.5 m.

Further information can be found in Banfield (1974).

Whales inhabit open water, areas of broken ice, and leads, since they require relatively large areas of open water in which to surface and breathe. Most Arctic species of seals prefer to live amongst drifting ice or at the edge of the pack ice. Solitary forms, such as ringed and bearded seals, are often found in areas of complete ice cover, where they maintain open breathing holes by continually breaking the growing ice over the holes. Both seals and walrus spend a great deal of time out of the water on haul-out areas, such as rocks, beaches or floating ice.

TABLE 3.

Walrus and Seals - in order of approximate abundance in the Canadian Arctic.

Name	Distribution in Canadian Arctic	Migrations	Feeding habits	Social habits	Preferred habitat	Known diving depths	Known dive durations	Typical adult length/weight
Ringed Seal (*Phoca hispida*)	Holarctic	Local, coastal	Prefer large crustacean plankton & small fish	Solitary	Coastal landfast ice; polar pack	100 m	20 min.	135 cm/91 kg
Harp Seal (*Phoca groenlandica*)	Eastern Arctic	Migrate into Arctic region in summer	Prefer small fish and large crustacean plankton	Gregarious - migrate in large groups (100-1000) & then disperse	Pelagic; edge of pack ice; ice-infested waters	275 m	15 min.	180 cm/180 kg
Bearded Seal (*Erignathus barbatus*)	Holarctic	None known	Prefer benthic invertebrates	Solitary	Shallow seas over continental shelves	Probably shallow	?	280 cm/400 kg
Walrus (*Odobenus rosmarus*)	Eastern Arctic; extreme western Beaufort Sea	Pacific walrus migrate; Atlantic do not	Prefer benthic invertebrates, primarily molluscs	Gregarious - live in large herds (1000's)	Shallow seas; need haul-out areas (beaches, rocks, ice-floes)	Less than 100 m	?	Male : 340 cm/1200 kg Female : 280 cm/700 kg
Hooded Seal (*Cystophora cristata*)	Davis Strait; Baffin Bay	Migrate into Arctic region in summer	Prefer fish and benthic invertebrates	Gregarious during migration, breeding and moulting	Pelagic; edge of pack ice	75 m	18 min.	Male : 230 cm/350 kg Female : 200 cm/300 kg
Harbour Seal (*Phoca vitulina*)	Eastern Arctic; western Beaufort Sea	Migrate into Arctic region in summer	Prefer fish; some molluscs eaten	Gregarious on land (herds up to 500), but forage alone	Coastal waters, bays, harbours, coastal rivers	100 m	23 min.	175 cm/140 kg

3.2.2.2 Marine Mammals and Diving

All true marine mammals dive for food and are therefore adapted to changes in hydrostatic pressure. Among pinnipeds, the Weddell seal (*Leptonychotes weddelli*) is the most notable diver, reaching depths of 600 m and being capable of staying submerged for up to 43 minutes (Kooyman, 1966). The sperm whale (*Physeter catodon*) is the pre-eminent diver amongst the cetacea; drowned specimens have been found entangled in submarine cables from depths of 900 m and 1134 m (Kooyman and Andersen, in Andersen, 1969). Maximum descent and ascent rates for both cetacea and pinnipedia range from about 100 to 140 m/min.

The adaptions necessary to permit marine mammals to withstand the pressure changes involved in deep diving are found primarily in the air-filled spaces of the body - notably the lungs, respiratory passages, outer and middle ear and accessory sinuses. Since the air-filled spaces of the body are the primary sites of damage to land mammals by underwater shock waves, adaptations which allow marine mammals to tolerate pressure changes may also make them resistant to damage from shock waves.

3.2.2.3 Thorax

The thorax of marine mammals is much more flexible than that of land mammals. Very few ribs are connected to the sternum with costal cartilage - especially in cetaceans - and the costal cartilage itself is flexible. Some Odontocetes (toothed whales) have "floating ribs", unconnected either to the sternum or to other ribs. Such a loosely-connected thoracic cage may not reduce the effects of shock waves on the lungs, since a rigid shield may be necessary to afford considerable protection against damage (see 3.2.1.3 above).

3.2.2.4 Respiratory System

Respiratory passages and lungs of marine mammals, particularly cetaceans, are highly modified for diving. Concerning the cetacean respiratory system, Simpson and Gardner (in Ridgway, 1972) state : "Compared to terrestrial mammals, there is a striking increase in the amount of supportive structures, namely cartilage, collagen, smooth muscle and elastic tissue in the peripheral portions of the lung." Extensive supportive structures are also found in the upper airways. Cartilaginous support extends from the trachea into the smaller airways up to the junction with alveolar ducts. Dense layers of elastic tissue, just beneath the mucous membrane, encircle and connect the cartilage. All these supportive tissues probably make cetacean lungs and airways less vulnerable to damage by shock waves, since the boundaries between tissue and air are not as fragile as in land animals.

The lung structure of pinnipeds, especially seals, is more similar to that of land mammals, but there are other modifications of the respiratory system which are shared by both pinnipeds and cetaceans. Table 4 shows some characteristics of the respiratory systems of a seal, a small cetacean, and man. The lung size relative to body size of marine mammals does not differ much from that of land mammals. However, the ratio of tidal air volume to the total lung volume, and the ratio of air passage volume to the total air volume are higher for marine mammals. These are modifications for deep diving. Increased tidal air means that more air in the lungs is renewed with each breath - facilitating rapid gas exchange. Larger relative air passage volume may permit total lung collapse during deep dives. Lungs are usually placed dorsally, and the diaphragm typically extends obliquely across

the thoracic cavity; thus, the lungs can completely flatten against the dorsal thoracic wall. The flexible thorax of these animals permits such a collapse, with the compressed air from the lungs being forced into the more rigid air passages. The Weddell seal, a particularly deep diver, has cartilaginous support around the trachea in the form of incomplete, flattened rings. This modification would allow further collapse of even the trachea under intense compression.

TABLE 4. Comparison of Respiratory Systems

	Seal		Small Cetacean	Man
Lung volume (litres)	42		55	42
Tidal air (litres)	15		49	7
Ratio of air passages/ total air	Inspir-ation	Exhal-ation	1/17	1/30
	1/19	1/5		
Depth of lung collapse (metres)	180	40	160	290

Seals generally exhale before diving, or during the initial part of the dive, whereas some cetaceans have been observed to dive after inspiration [Ridgway, in Ridgway (1972)]. Thus, the diving depth at which total lung collapse occurs is probably less for pinnipeds than for cetaceans. Nevertheless, when the lungs are collapsed, they will certainly be less vulnerable to damage from shock waves. Upper air passages in land mammals (and probably marine mammals as well) are not primary damage sites.

3.2.2.5 Ears and Other Air-spaces in the Head Region.

The middle and outer ears, and the various sinuses associated with the ears of diving mammals also have protection against pressure changes. True seals (Phocidae - this group includes all the common seals of the Arctic) and cetaceans do not have any external ears. Instead, the external ear opening is usually a small pore or slit on the side of the head region. In pinnipeds, the external auditory canal is long and narrow and is supported

by cartilage. The canal is also lined with a thick, highly vascularized "cavernous" tissue; it may expand during a dive by filling with blood and thus occupy the air-filled space in the canal. The seal's external ear-opening is usually closed while diving. Very dense bone surrounds the middle ear cavity, which is also lined with thick cavernous tissue, called the *corpus cavernosum*. Seal biologists believe that this tissue fills with blood as the seal descends in order to equalize the air pressure within the middle ear cavity with the pressure in other ear passages connected to the inner ear via the eustachian tube.

In toothed whales, the external ear opening is very small, or closed entirely. The auditory canal and the middle ear are lined with cavernous tissue; the middle and inner ears are also surrounded by a system of air sinuses filled with a foam formed from an oil-mucous emulsion. These sinuses are bounded closely by the bones of the skull and by thick cavernous tissue (P. E. Purves, in Norris, 1966). As in the pinniped ear, the cavernous tissue probably fills with blood as the animal dives, thus expanding into the cavity to equalize the internal air pressure with the external hydrostatic pressure.

It appears that the air spaces associated with the ears of pinnipeds and cetaceans are well protected against shock-wave damage, because these spaces are typically surrounded by bone or cartilage and are lined with cavernous tissue which is itself bounded by a tough, fibrous membrane. During deep dives, these air spaces might be reduced in size by filling of the cavernous tissue with blood. The eardrum of pinniped and baleen whales - it is not functional in toothed whales (S. Ridgway, pers. comm.) - may be damaged by shock waves. An injured animal may be partially incapacitated in this way, but it is not known to what extent pinnipeds and baleen whales rely on hearing for their survival. A ruptured eardrum could also cause a fatal secondary infection of the middle ear.

As noted above, toothed whales do not have a functional eardrum. How sound is transmitted to their inner ears has not yet been clearly demonstrated, but some workers believe that sound waves are transmitted via various bodies of fat to the bone surrounding the inner ear. These mammals are thought to use a system of echolocation for navigation and hunting (see K. S. Norris, in Andersen 1969), so that any damage to their hearing systems might be fatal in the long-term. Shock waves, not sufficiently powerful to cause any gross physical damage to the animal, might travel along the normal routes of sound transmission within the animal to the inner ear. There, they might be powerful enough to disrupt the delicate bones and nerves of the inner ear.

The highly modified nostrils (nares) of cetaceans contain additional air-containing sacs and passages. The lining of these passages is tough and elastic in sperm whales (Clarke, 1978), and

it seems possible that this is the case in all whales. If so, the nostrils are not likely to be principal sites of damage by shock waves.

3.2.2.6 Viscera

Other principal damage sites in *terrestrial* mammals are regions of hollow viscera containing gas. I have been unable to find any references in the literature to intestinal gas bubbles in marine mammals. Such gas bubbles are *probably* uncommon, since the presence of significant quantities of gas in the intestinal tracts of animals which spend a great deal of time passing through pressure differences of 20 atmospheres or more could cause considerable discomfort, pain, and even injury.

3.2.2.7 Skin and Body Walls

In the review of the effects of shock waves on terrestrial mammals (section 3.2.1 above), it is noted that larger animals are less vulnerable to damage than small animals. This is likely a function of the thicker body walls of the larger mammals. Most marine mammals are large animals (see Tables 2 and 3), possessing thick body walls. The skin of cetaceans consists of a tough epidermis, usually less than 1 cm thick, under which is the thinner dermis, composed mainly of thick bundles of connective tissue. Below the dermis lies the hypodermis, or blubber, a layer of fatty tissue - up to 60 cm thick in larger whales. The skin of pinnipeds is similar, except that all layers are proportionately thinner. The blubber layer of the ringed seal ranges from 10 mm to 63 mm in thickness, depending on the size of the animal and the season (McLaren, 1958). Arctic pinnipeds (except walrus) also have a layer of fur which, along with the skin, is waterproofed by a thin film of oil.

Norris (1975) measured the acoustic properties of the blubber coat in porpoises. He found that, although sound easily entered the blubber coat, "the blubber/muscle interface proved an excellent sound reflector." Shock waves are reflected and absorbed in a roughly similar manner to low amplitude sound waves. Thus, although only a small fraction of shock-wave energy would be reflected at the skin and water interface, a considerable fraction would be reflected at the blubber and muscle interface. This would correspondingly reduce the peak pressures of the shock wave entering the body of the animal. The unwettable skin and fur of pinnipeds would not be a good acoustic couple between the water and the body of the animal, and could reduce the intensity of a shock wave more than would the wet skin of cetaceans.

4. LETHAL RANGE PREDICTIONS.

4.1 Damage to Fish.

Rules have been developed for the prediction of lethal ranges of explosives under specified conditions; the most useful and accurate of these damage rules are reviewed below. 'Lethal range', in the following sections, is defined as the range at which 50% of fish are expected to be killed outright. It is reasonable to assume that all fish within this range will be killed, because the 50% not killed immediately will probably be somewhat disabled, and vulnerable to predation.

4.1.1 Lethal Ranges for Explosives

Early researchers used the maximum shock wave overpressure (P_{max}) as the predictor of lethal ranges. However, further experimentation shows that P_{max} is not a good predictor, since the measured lethal P_{max} varies over wide limits for a given species of fish, is different for different species of fish (Hubbs and Rechnitzer, 1952; Hubbs *et al*, 1960), and varies with the type of explosive used (Sakaguchi *et al*, 1976).

The lethality of an underwater explosion is determined by : the size of the fish, the species of fish, the orientation of the fish relative to the blast, the amount and type of explosive used, the water depth, the detonation depth, and the material and contours of the bottom. Some parameters have been found which can be used to predict roughly the potential damage to a fish under specified conditions, but a general rule for predicting potential damage to any fish population, under *any* set of conditions, has not been developed, simply because of the number of variables involved and their complex inter-relationships. In spite of this, some simple damage rules, applicable under restricted sets of conditions, have been developed.

4.1.1.1 Lethal Energy Flux Density

Sakaguchi *et al* (1976) found that the energy flux density (E_f), defined as

$$E_f = \frac{1}{\rho_o C_o} \int [P(t)]^2 dt$$

was a good predictor of the damage caused to fish in several different experimental situations. The lethal level of E_f was found to be 300 Joules/m^2. Unfortunately, they calculated E_f directly from the recorded pressure signatures, using numerical methods rather than relating the expected E_f to the charge weight. In order to predict the potential lethality of an explosion, an alternate method of determining E_f is necessary.

MacLennan (1977) used E_f equal to 300 Joules/m^2 and calculated the theoretical lethal range (R_L) where this energy flux density would exist for point source explosives of weight W in open water, assuming no surface or bottom reflections. The lethal range is given by

$$R_L = 15.47 \times W^{0.496} \quad (R \text{ in metres, } W \text{ in kg}).$$

This range is probably greater for fish near shallow bottoms because of the addition of the bottom-reflected pulse. Similarly, the lethal range would be reduced for fish near the surface because of the cancelling effect of the surface-reflected pulse.

MacLennan's energy flux density predictor was tested against several sets of experimental data. It did not predict the results of Roguski and Nagata (1960), but did satisfactorily predict the results of Hubbs *et al* (1960) and Falk and Lawrence (1973). It was also a reasonably good predictor for some of the data of Tyler (1960), but did not predict the increase in lethal range which occurred with increasing depth of detonation.

4.1.1.2 Lethal Cavitation Zone

Christian (1973) defined two lethal zones for underwater explosions. The first is the immediate vicinity of the charge where P_{max} and other factors are the primary cause of damage; and the second is the bulk cavitation zone - usually the larger of the two zones - which is at or near the surface. The negative pressures associated with the cavitation zone can severely damage the gas bladders of fish by decompression and over-extension (see 3.1.2 above). Actual cavitation of the fishes' body fluids has also been suggested as a possible mechanism of damage. Gas bubbles resulting from such cavitation could collect in the vascular system, resulting in embolism and, if large enough, could cause mechanical damage to blood vessels and organs.

Some approximations to define the location and extent of the cavitation zone for detonation depths less than 15.2 m and charge sizes less than 450 kg have been developed by Christian (1973). The cavitation zone is approximated as a cylinder of radius R and height H situated directly above the charge, with the upper end of the cylinder being the water surface. The dimensions of the cylinder are defined by the following expressions :

$$R(m) = X \cdot (2.2 \cdot W)^{\alpha} \qquad W = \text{charge weight (kg)}$$
$$X = 39 \cdot \sqrt{D} \qquad D = \text{detonation depth (m)}$$
$$\alpha = .036 \cdot \sqrt{D}$$
$$H = 3 \cdot W^{0.3}$$

This model did not adequately predict the experimental results of Roguski and Nagata (1970); this is expected since the charges were detonated under approximately 75 cm of ice. In this case, the surface-reflected wave may not have been a simple negative pressure wave, making the cavitation zone small or non-existent. Christian's model also did not predict the results of Tyler (1960), or of Falk and Lawrence (1973).

Because this model seemed to be such a poor predictor of experimentally-determined fish mortality, I examined some other results from the literature to look for evidence of a lethal surface cavitation zone. Hubbs and Rechnitzer (1952) investigated the effects of 'jetted' charges (these are explosives buried in the sea-bottom by means of a water jet) on caged fish. In their data, 20 experiments are described in which fish were placed in cages - some near the surface and some near the bottom - and in which some or all fish at either location were killed. Of these, there were eight cases in which surface fish were killed where no (or few) fish were killed near the bottom. Of these eight cases, four cases were found to have a significantly (95% level or better, using the chi-square statistic) greater proportion of fish killed at the surface. The implication of this analysis was that fish at the surface were more likely to be damaged than fish near the bottom, *even though* they were further from the explosion than those near the bottom. However, no similar conclusion could be reached from my examination of data from Gaspin (1975), in which the presence or absence of cavitation was determined through direct observation of pressure-time signatures. Again using the chi-square statistic, I found that, for cases where the impulse was between 0.55 and 2.07 bar-msec (the region where lethality of explosions was most variable), the presence or absence of cavitation had no significant effect on the lethality of an explosion.

The above analysis suggests that a lethal surface zone exists, but that it may not be associated with the cavitation zone. If the surface cavitation zone is lethal to fish, a better model has to be developed to define its extent, because Christian's model does not fit published results.

4.1.1.3 Lethal Impulse.

Yelverton *et al* (1975) present data which support the hypothesis that the *impulse* of the shock wave is the determining factor in predicting its lethality to fish. They also report that the lethal level of impulse increases with fish weight. Figure 6 demonstrates the consistency of impulse as a predictor of lethality, especially when compared to P_{max}. As the depth of the target fish increases, the maximum overpressure causing 50% mortality decreases. However, the impulse values corresponding to 50% mortality remain much the same.

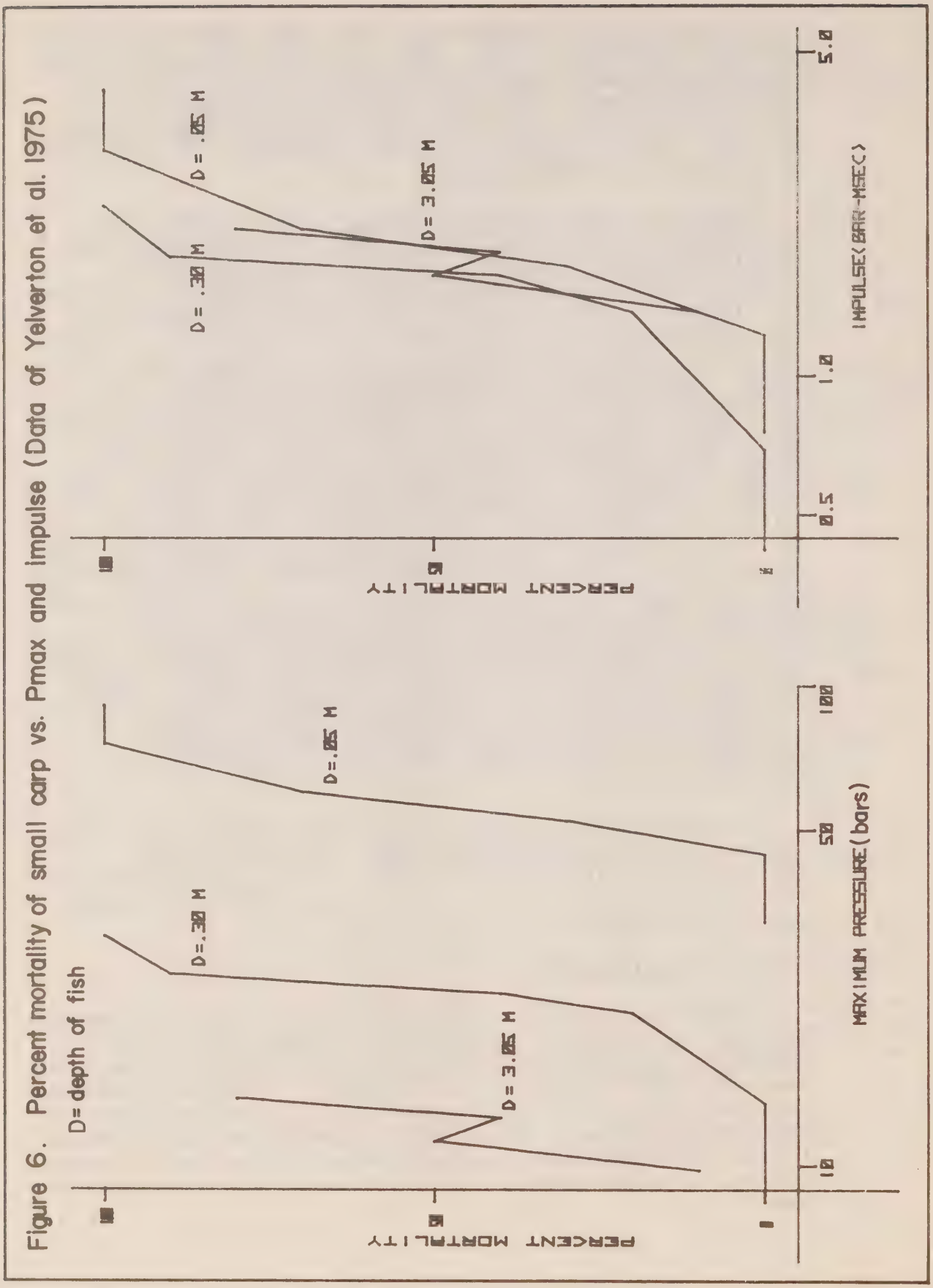


Figure 6. Percent mortality of small carp vs. Pmax and impulse (Data of Yelverton et al. 1975)

A lethal range model which includes the variables of fish sizes, depth of fish, charge size and depth of detonation, is given in Yelverton *et al* (1975). Although the computations are tedious, the results seem worthwhile. This rule roughly predicted the experimental results of Hubbs *et al* (1960), Tyler (1960), Roguski and Nagata (1970), and Falk and Lawrence (1973).

The typical size and the depth distribution of the fish population must be known in order to predict lethal ranges using this model. First, the impulse (I_1) corresponding to 50% mortality for fish of the particular size of interest is taken from Figure 7. Then the scaled impulse: $I_1/(\text{charge weight})^{1/3}$ and the parameter A, equal to the depth of detonation x depth of fish/$(\text{charge weight})^{2/3}$ are calculated. Figure 8 shows the family of curves of scaled lethal slant range vs the scaled impulse for many values of the parameter A. The curve for the particular value of A calculated is then found on Figure 8. The point where this curve intersects the value for the scaled impulse gives the value for the scaled lethal slant range. This scaled slant range can then be converted to the true lethal slant range by multiplying by $(\text{charge weight})^{1/3}$. Sample calculations are shown in Section I.

The data used to compile this model were collected under very restricted conditions: for example, the tank in which the experiments were performed had a maximum depth of about 9 m, and all charges used were 0.45 kg spheres. However, the model seems to have wide applicability, as evidenced by the fact that it successfully predicted field results from many different situations.

4.1.2 Lethal Ranges for Air-guns

All published results indicate that air-guns are not a significant hazard to fish. Falk and Lawrence (1973) tested the effects of a 4.9ℓ air-gun, operated at 138 bar, on caged fish at various depths and found that no damage was done to any fish. They also report that there were no fish kills observed in 16 km of seismic prospecting using air-guns on the Mackenzie River. Weinhold and Weaver (1973) tested the effects of both a single air-gun (0.33ℓ) and an 8-gun array (total volume 3.9ℓ) operated at 138 bars. The target fish in this case were Coho salmon fingerlings at distances of from 1 to 10 m. Again, there were no deaths or evidence of stress in any case. Kostyuchenko (1973) compared the effects of an air-gun (5ℓ at 142 bars) and small (50 g) charges of TNT on fish eggs. The survival rates for eggs (control values in brackets) at a distance of 5 m from the source were :

TNT - 30.8% (98.2%); Air-gun - 87.7% (92.3%).

The TNT certainly caused some damage, but the air-gun had little or no effect on the eggs.

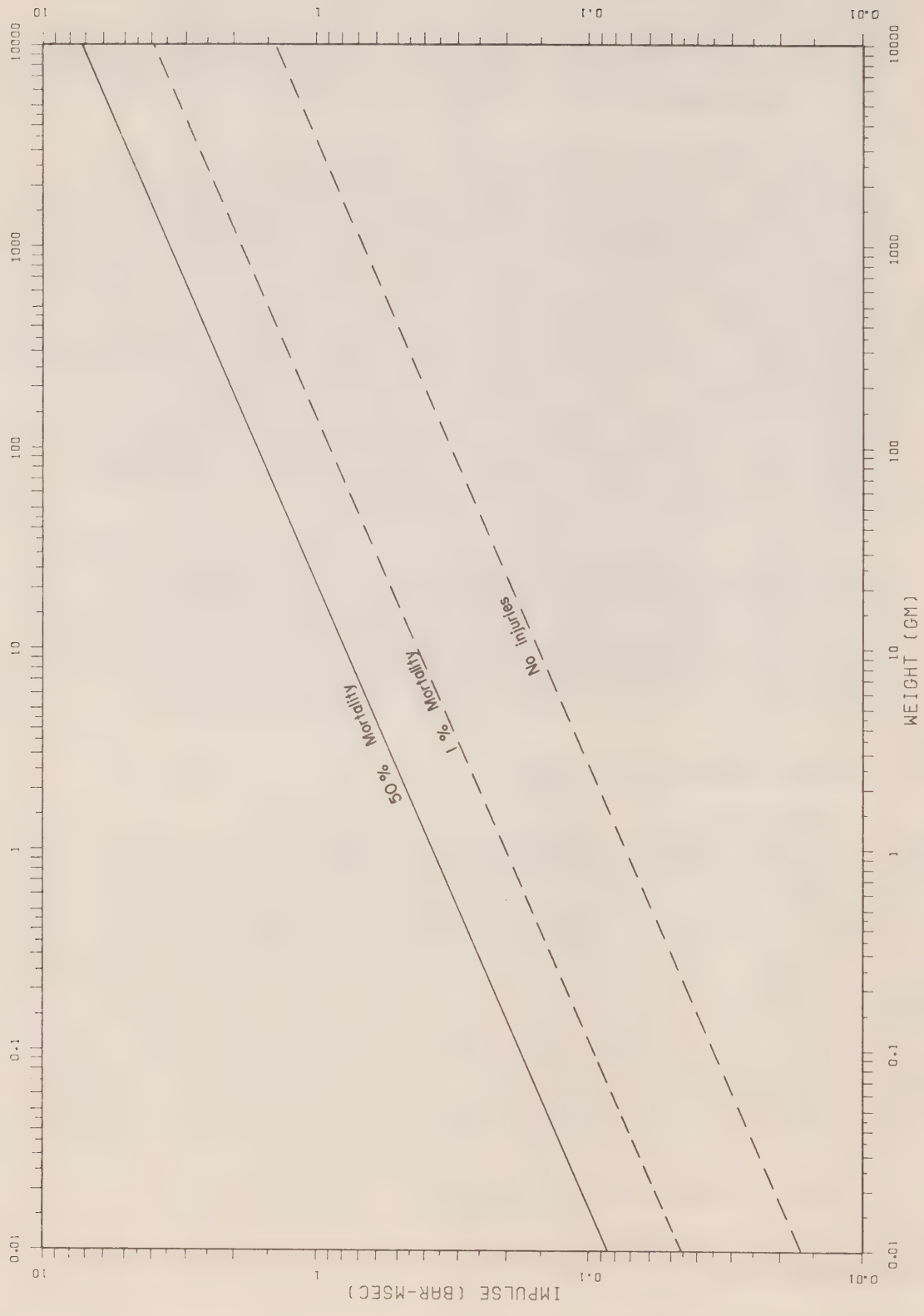


Figure 7. Lethal Impulse vs Weight for Fish.(after Yelverton *et al.*, 1975).

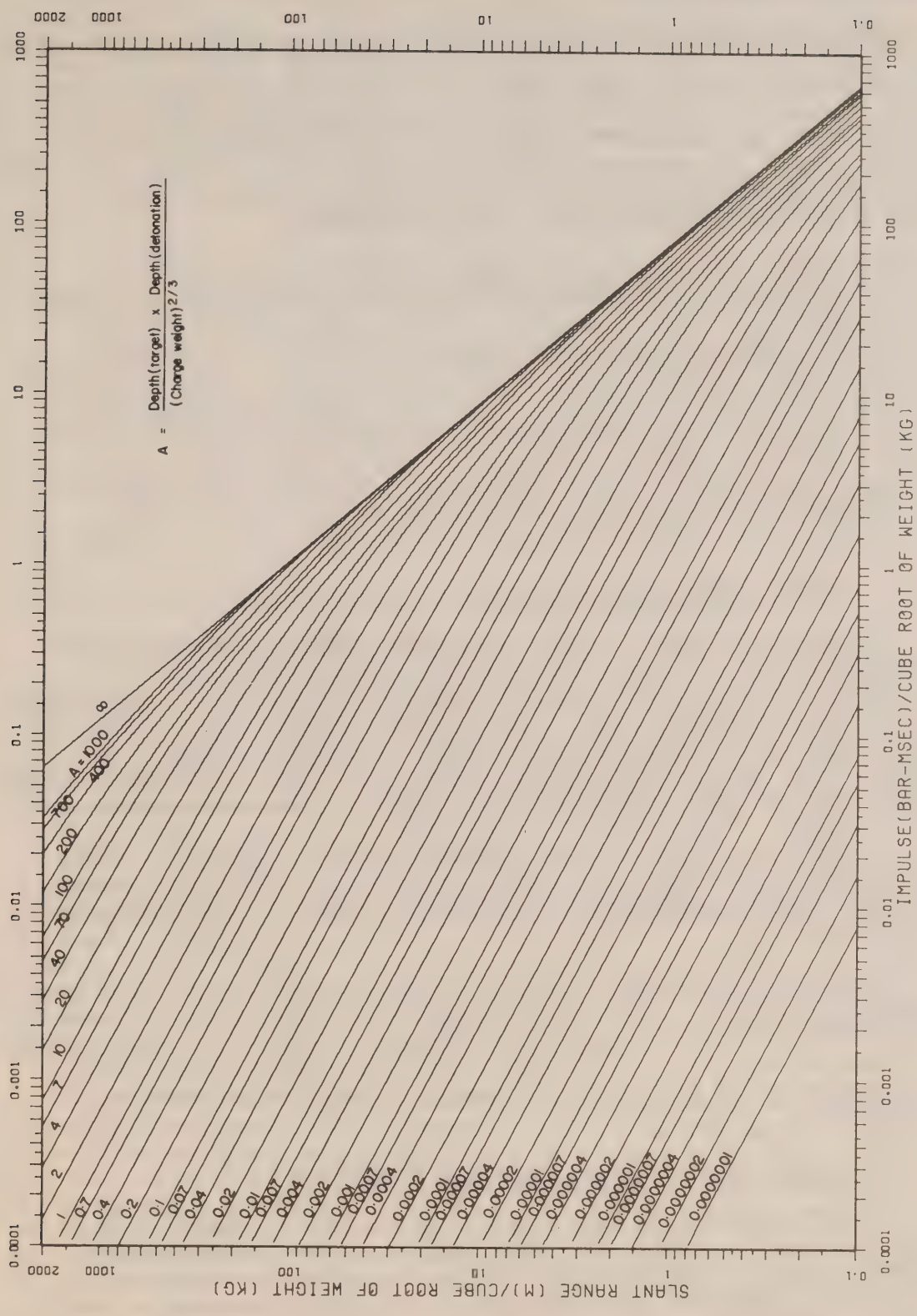


Figure 8. Curves for calculating lethal ranges from impulse (after Yelverton *et al.*, 1975).

4.2 Damage to Marine Mammals

An analysis of the information presented in 3.2.2 shows that marine mammals are probably less vulnerable to *gross* physical damage from underwater shock waves than are land mammals of comparable size. This is primarily because of adaptations to pressure changes which enable these animals to dive and, secondarily, because of the increased thickness of their body walls. In addition, when marine mammals are diving - particularly when they are deeper than about 150 m - they will probably be less vulnerable than when they are at or near the surface.

The hearing systems of marine mammals may be more vulnerable to damage. Baleen whales and pinnipeds could suffer hearing damage through ruptured ear-drums. Toothed whales, especially, may suffer hearing damage from sub-lethal shock waves because of the direct sound-conduction path to the inner ear via blubber and fat (see 3.2.2.5). Further research is warranted to assess the effect of small amplitude shock waves on the hearing of these and other marine mammals. Seeley *et al* (1976) developed and used a portable system to measure the hearing ability of marine mammals over the range of 5 kHz to 200 kHz. A similar system could be used to determine the effect of small underwater explosions on the hearing of such important arctic mammals as the beluga and the ringed seal.

4.2.1 Lethal Ranges for Explosives

Evidence presented in 3.2.1.2 indicates that the impulse of the shock wave is its prime damaging factor. Yelverton *et al* (1973) determined the degree of damage to submerged land mammals corresponding to different impulse levels. These impulse levels, shown in Table 5, were found to be approximately constant for animals ranging in size from 5 kg to 40 kg. Adult marine mammals are often considerably larger than this, and are probably less vulnerable to shock-wave damage than land mammals. These impulse levels therefore include a large, built-in safety factor when applied to marine mammals. Hearing damage to Baleen whales and seals can possibly be predicted from these values, but the impulse levels which cause hearing damage in toothed whales remain unknown.

To predict the range at which various levels of damage to marine mammals are likely, the impulse levels in Table 5 can be used with the method for calculating slant ranges given in 4.1.1.3 above. The information required is: explosion depth, the depth of the animal, and the weight of the charge. A sample calculation is shown in Section I.

4.2.2 Lethality of Air-guns to Marine Mammals

Since air-guns have been found to be essentially harmless to fish, it is extremely unlikely that they would cause any gross damage to marine mammals. Some damage to the hearing of these animals *might* occur but, since the sensitivity of their auditory systems to small-amplitude shock waves is unknown, the degree of damage, if any, is impossible to predict.

TABLE 5. Underwater Blast Criteria for Mammals Diving Beneath the Water Surface (from Yelverton *et al*, 1973.

Impulse, bar-msec	Criteria
2.76	No mortality. High incidence of moderately severe blast injuries, including eardrum rupture. Animals should recover on their own.
1.38	High incidence of slight blast injuries, including eardrum rupture. Animals would recover on their own.
0.69	Low incidence of trivial blast injuries. No eardrum ruptures.
0.34	Safe level. No injuries.

5. METHODS OF REDUCING DAMAGE FROM SEISMIC EXPLOSIVES

Several techniques and strategies have been suggested to minimize the damage to fish and marine mammals caused by large, point-source explosives used in seismic exploration. Different kinds of explosives (slower rise times, lower P_{max}) or physical arrangements of explosives (coils, arrays) have been tested with limited success (Jakosky and Jakosky, 1956). It has proved difficult to develop explosive sources which will produce useful seismic records and still be relatively harmless to fish.

Another technique is the detonation of small "scaring charges" to frighten fish away prior to detonating large charges. However, evidence suggests that fish are, instead, *attracted* to explosion sites, where they can feed on disturbed benthos or smaller injured or stunned fish (Aplin, 1947; Fitch and Young, 1948). The same may be true of marine mammals; for example, a grey seal was seen to be swimming, and apparently feeding on injured fish, near the site of a wreck where large charges were being detonated (B. Beck, Bedford Institute of Oceanography - pers. comm.).

Burying charges in the sea bottom to minimize damage is another method which has been tested. This method is used in shallow coastal regions where it is often necessary to use relatively large charges to obtain useful seismic records. Hubbs and Rechnitzer (1952) found that the peak shock-wave pressure in the sea near the bottom diminishes inversely as the 2.6 power of the depth of the buried charges. This attenuation rate is more than double that in open water, indicating that considerable shock-wave energy is absorbed and reflected downward by bottom materials - thus reducing the peak pressure of the shock wave which is transmitted into the water. The Fisheries and Marine

Service of Environment Canada has prepared guidelines for arctic regions, giving the required depth of burial for charges of varying weights (FMS, 1975). Although charge burial is a somewhat effective technique, it will only reduce, not eliminate, damage to nearby aquatic life.

6. SUMMARY

There is no doubt that underwater shock waves can harm fish and marine mammals. The problem is to determine how much they might be damaged by any proposed explosion or other shock-wave-producing process. The decision of whether or not to proceed will then depend on criteria established for acceptable damage levels. It was not the purpose of this report to set such criteria, but to present information enabling the prediction of damage arising from a proposed activity. Reasonable predictions can be made in nearly all cases, provided that the kinds of fish and mammals likely to be affected and their spatial distributions are known. These predictions depend on relationships between shock wave impulse and lethal range, described in sections 4.1 and 4.2.

Air-guns used in seismic exploration are harmless to both fish and marine mammals, according to all results published in the literature. Typical AQUAFLEX charges (8 m lengths, 8.5 g/m), used in offshore under-ice seismic exploration, are also virtually harmless because of the linear shape of the charge and the small quantity of explosive which they contain. However, point source charges weighing only 0.2 kg can cause damaging impulses at ranges of up to 10 m.

If only small amounts (less than 5 kg) of explosive are used in deep, open water, marine mammals are probably safe from gross physical damage, provided they are more than 60 m from the detonation point. However, damage to their hearing ability could occur at even greater distances. It is possible to estimate safe distances for the hearing of baleen whales and pinnipeds using the criteria outlined in Table 5, but the effects of sublethal shock waves on the hearing of toothed whales, such as beluga and narwhal, remain unknown. These effects are of importance, since these animals use their hearing extensively in foraging for food, in navigation and possibly in communication. Thus, it is important that we determine the extent to which sublethal shock waves can damage the hearing of these animals.

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APPENDIX 1.

Numerical Integration to Determine the Pressure Distribution around a Linear Charge.

Reference : Cole (1948), pp. 248 - 253.

Consider a linear charge of length L. The origin of the co-ordinate system to be used is the detonation end of the charge, and the charge defines the positive x-axis. The y-axis is perpendicular to the charge length. To determine the pressure at any point Q(x',y') and time 't', we treat the linear charge as a series of very small spherical charges, each at location (x,o), and sum their contributions to the pressure at Q. Thus, we integrate over the effective length of the charge as follows :

$$P(x',y',t) = Pm \int_L \frac{e^{-\tau/\theta}}{r}\, dx$$

where Pm, θ are empirically derived constants.

$$\tau = t - \frac{r}{u} - \frac{x}{d} \quad \text{where r(range)} = \sqrt{(x - x')^2 + y'^2}$$

u = shock wave propagation speed

d = detonation speed of explosive.

The charge is detonated at time t = 0. For P to be non-zero, τ must be greater than or equal to zero. This defines the limits of the integration over the charge length. Since the integral cannot be solved explicitly, it was solved with a computer using numerical methods (small, finite increments of x and t are used to compute the sum).

Assumptions :

1. Neglect bottom or surface effects.
2. Assume that u (shock-wave speed)= c_o (local sound speed).

Values used in Integration :

1. For 46 grain PETN [Cole (1948), p. 252; Primacord 3 gm/ft] :
   Pm = 1.051 x 10^2 bars, θ = 17 μs.
2. Detonation speed for PETN = 6203 m/s.
3. Local sound speed c_o = 1448 m/s.
4. Increments used in numerical integration :
   time : 6 μs, charge length : .02 m.

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ABSTRACT

Physical, chemical and biological oceanographic observations are made from the weathership at Ocean Weather Station Papa, and between Esquimalt and Station Papa, on a routine continuing basis. Physical oceanography data only are shown, including surface observations and profiles obtained with bottle casts and conductivity-temperature-pressure instruments.

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INTRODUCTION

Canadian operation of Ocean Weather Station P (Latitude 50°00'N, Longitude 145°00'W) was inaugurated in December, 1950. The station is occupied primarily to make meteorological observations of the surface and upper air and to provide an air-sea rescue service. The station is manned by two vessels operated by the Marine Services Branch of the Ministry of Transport. They are the CCGS Vancouver and the CCGS Quadra. Each ship remains on station for a period of six weeks, and is then relieved by the alternate ship, thus maintaining a continuous watch.

Bathythermograph observations have been made at Station P since July, 1952. A program of more extensive oceanographic observations commenced in August 1956. This was extended in April, 1959 by the addition of a series of oceanographic stations along the route to and from Station P and Swiftsure Bank. These stations are known as Line P stations. The number of stations on Line P has been increased twice and now consists of twelve stations (Fig. 1). Bathythermograph observations and surface salinity sample collections, in addition to being made on Line P oceanographic stations, are also made at odd meridians at 40', i.e. 139°40'W, 141°40'W, etc. These stations are known as Line P BT stations. Data observed prior to 1968 have been indexed by Collins et al (1969).

The present record includes hydrographic, continuously sampled STP and surface salinity and temperature data collected from the CCGS Vancouver during the period 5 May to 21 June 1978.

All physical oceanographic data have been stored by the Marine Environmental Data Services Branch (MEDS), Fisheries and Environment Canada, 240 Sparks Street, 7th Floor West, Ottawa, Ontario, Canada, K1A 0E6. Requests for these data should be directed to MEDS.

Biological and productivity data are published in the Manuscript Report series of the Fisheries Research Board of Canada (FRB), Pacific Biological Station, Nanaimo, British Columbia, Canada. Requests for these data should be directed to FRB.

Marine geochemical data are for the Ocean Chemistry Group, Ocean and Aquatic Sciences, Environment Canada, Institute of Ocean Sciences, P.O. Box 6000, Sidney, B.C., V8L 4B2.

PROGRAM OF OBSERVATION FROM CCGS VANCOUVER, 5 MAY - 21 JUNE 1978 (P-78-4)
(MEDS Ref. No. 15-78-004)

Oceanographic observations were made by Ms. T. Mullin of the Pacific Biological Station, Nanaimo, B.C. and officers of the CCGS Vancouver.

En Route to Station P

Line P Stations 1 to 10 and 12 were occupied and an STP profile made to 1500 metres or near bottom. The STP scheduled for Station 11 was missed. The ship did not stop as it was behind schedule. No hydrocasts were made.

Samples for salinity were collected from the seawater loop at whole and half stations 1 to 9,10,12 and 12½. Surface bucket samples for salinity were collected at Stations 1 to 5, 9½, and 10½ to 11½.

The surface temperature recorder and thermosalinograph were run continuously.

XBT's were taken at Stations 5½,6½,7½,8½,9½, and 10½ to 12½. Mechanical BT's were taken at all other stations.

On Station P

The oceanographic program was carried out as follows:

Physical Oceanography

1) Profiles of salinity and temperature were obtained from 6 hydrographic casts (2 casts to 4200 metres and 4 casts to 1500 metres).

2) Twenty STP profiles to 1500 metres were obtained.

3) BT's or XBT's were taken every three hours to coincide with meteorlogical observations, encoded and transmitted according to the IGOSS format.

Marine Geochemistry

1) Salinity samples were collected daily at 0000 hrs GMT from the seawater loop. Daily temperature comparisons were made.

2) Five P.O.C. samples were collected from the seawater loop. Two profiles to 1500 metres were also taken.

3) One tarball tow was completed.

Biological Oceanography

Samples collected were as follows:

1) Thirty-three vertical plankton hauls to 150 metres.
Five vertical plankton hauls to 1200 metres.
Three sets of 10 vertical plankton hauls to 150 metres.
Three 26 hour series of vertical plankton hauls to 150 metres (18 hauls taken per series).
Three sets of vertical plankton hauls from varying depths.

2) Twelve horizontal plankton hauls taken at dusk.

3) A weekly Secchi disc reading taken at local noon.

4) Nitrate samples were collected daily from the seawater loop.

En Route from Station P

Line P Stations 12 to 4 and 2 to 1 were occupied and an STP profile made to 1500 metres or near bottom. No hydrocasts were made. The ship did not stop at Station 3 due to high winds and swells.

Samples for salinity were collected from the seawater loop at whole and half stations 12 to 1. Surface bucket samples for salinity were collected at Stations 5 to 1.

The surface temperature recorder and thermosalinograph were run continuously.

XBT's were taken at whole and half stations 12½, 11½, 10½, 9½, 8½, 8, 7½, 6½, 5½ and 3. Mechanical BT's were taken at all other stations.

Observations for Other Agencies

1) Marine mammal observations were made by the ship's officers for Mr. I. McAskie, Fisheries Research Board of Canada, Pacific Biological Station, Nanaimo, B.C., Canada.

2) Bird observations were made by the ship's officers for Dr. M. Myres, University of Alberta, Calgary, Alberta, Canada and Mr. J. Guiguet, Curator of Birds and Mammals, Provincial Museum, Department of Provincial Secretary and Travel Industry, Victoria, British Columbia, Canada.

3) Air CO_2 samples were taken weekly in duplicate for Scripps Institution of Oceanography, La Jolla, California, U.S.A.

Data were processed for publication by Ms. M. Sainsbury of Seakem Oceanography Ltd., Sidney, B.C.

OBSERVATION PROCEDURES

Observations for salinity, oxygen and temperature from all hydrographic casts, including the surface, were obtained with Niskin water sample bottles equipped with either Richter and Wiese and/or Yoshino Keiki Co. reversing thermometers. Two protected thermometers were used on all bottles and one unprotected thermometer was used on each bottle at depths of 300 m or greater. The accuracy of protected reversing thermometers is believed to be $\pm$ 0.02°C.

The daily surface water temperatures were measured from a bucket sample using a deck thermometer of $\pm$ 0.1°C accuracy. The daily surface salinity samples were obtained from the seawater loop. When the seawater loop was not operational these samples were obtained with a bucket, and are indicated with a 'b' in this data record.

Salinity determinations were made aboard ship with either an Autolab Model 601 Mark III inductive salinometer or a Hytech Model 6220 lab salinometer. Accuracy using duplicated determinations is estimated to be $\pm$ 0.003°/oo.

Depth determinations were made using the "depth difference" method described in the U. S. N. Hydrographic Office Publication No. 607 (1955). Depth estimates have an approximate accuracy of $\pm$ 5 m for depths less than 1000 m, and $\pm$ 0.5% of depth for depths greater than 1000 m.

The dissolved oxygen analyses were done in the shipboard laboratory by a modified Winkler method (Carpenter, 1955).

Line P engine intake continuous temperature on both ships was recorded by a Honeywell Electronik 15 Recorder. The temperature probe is at a depth of approximately 3 metres below the sea surface and the instrument accuracy is believed to be $\pm$ 0.1°C.

Each ship is equipped with a PLessey Model 6600-T thermosalinograph which is used, on Line P, for continuous recording of surface temperatures and salinities from the ship's seawater loop. The temperature probe is mounted at the seawater loop intake (approximately 3 metres below the surface) and the salinity probe and recorder are situated in the dry lab. The accuracy of this instrument is believed to be $\pm$ 0.1°C for temperature and $\pm$ 0.1°/oo for salinity.

STP profiles were taken with a Guildline Model 8700 STP system.

COMPUTATIONS

All hydrographic data were processed with the aid of an IBM 370 computer and a UNIVAC 1100 computer. Reversing thermometer temperature corrections, thermometric depth calculations and accepted depth from the "depth difference" method were computed. Extraneous thermometric depths caused by thermometer

malfunctions were automatically edited and replaced. A Calcomp 565 Offline Plotter was used to plot temperature-salinity, and temperature-oxygen diagrams, as well as plots of temperature, salinity, and dissolved oxygen vs $\log_{10}$ depth. These plots were used to check the data for errors.

Missing hydrographic data were obtained using a weighted parabolas interpolation method (Reiniger and Ross, 1968). These data are indicated with an asterisk in this data record.

Data values which we suspect but which we have included in this data record are indicated with a plus. These data have been removed from punched card and magnetic tape records.

Analog records from the salinity-temperature-pressure instrument have been machine digitized, then replotted using the Calcomp plotter.

Digitization was continued until original and computer plotted traces were coincident. Temperature and salinity values were listed at standard pressures; computed from the entire array of digitized data.

The headings for the data listings are explained as follows:

PRESS	is pressure (decibars)
TEMP	is temperature (degrees Celsius)
SAL	is salinity (parts per thousand)
DEPTH	is reported in metres
SIGMA-T	is specific gravity anomaly
SVA	is specific volume anomaly
THETA	is potential temperature (degrees Celsius)
SVA (THETA)	is potential specific volume anomaly
DELTA D	is geopotential anomaly (J/kg)
POT EN	is potential energy in units of 10^8 ergs/cm^2
OXY	is the concentration of dissolved oxygen expressed in millilitres per litre
SOUND	is velocity of sound in m/sec

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LOG OF HYDROGRAPHIC AND STP OBSERVATIONS

CONSEC. #	POSITION	DATE (GMT)	TIME (GMT)	STP(m)	HYDROCAST (m)	COMMENTS
1	125-33°W	05/05/78	0106	90		
2	126-00°W	06/05/78	0302	100		
3	126-40°W	06/05/78	0500	1200		
4	127-40°W	"	0952	1200		
5	128-40°W	"	1209	1400		
6	130-40°W	"	1812	1400		
7	132-40°W	07/05/78	0010	1400		
8	134-40°W	"	0600	1400		
9	136-40°W	"	1220	1400		
10	138-40°W	"	1858	1400		
11	142-40°W	08/05/78	0950	1400		
12	P	"	2120	1350		
13	P	10/05/78	1714	1400		
14	P	"	1800		1500	T,S
	P	11/05/78	1700		4200	T,S
15	P	12/05/78	1710	1400		
16	P	15/05/78	1708	1400		
17	P	15/05/78	1750		1500	T,S
18	P	17/05/78	1713	1350		
19	P	20/05/78	1708	1400		
20	P	22/05/78	1718	1400		
21	P	22/05/78	1800		1500	T,S
22	P	24/05/78	1712	1400		
23	P	27/05/78	1712	1400		
24	P	29/05/78	1718	1400		
25	P	29/05/78	1750		4200	T,S
26	P	31/05/78	1710	1400		
27	P	03/06/78	1714	1400		
28	P	05/06/78	1715	1400		
29	P	06/06/78	1713	1400		
30	P	06/06/78	1740		1500	T,S
31	P	08/06/78	1713	1400		
32	P	10/06/78	1709	1400		
33	P	12/06/78	1707	1400		
34	P	12/06/78	1745		1500	T,S
35	P	14/06/78	1745	1400		
36	P	17/06/78	1709	1400		
37	142-40°W	19/06/78	0315	1400		
38	140-40°W	"	1010	1400		
39	138-40°W	"	1630	1400		
40	136-40°W	"	2313	1400		

LOG OF HYDROGRAPHIC AND STP OBSERVATIONS con't

CONSEC. #	POSITION	DATE (GMT)	TIME (GMT)	STP (m)	HYDROCAST (m)	COMMENTS
41	134-40°W	20/06/78	0550	1400		
42	132-40°W	"	1225	1400		
43	130-40°W	"	1905	1400		
44	128-40°W	21/06/78	0111	1250		
45	127-40°W	"	0456	1350		
46	126-00°W	"	1027	90		
47	125-33°W	"	1205	100		

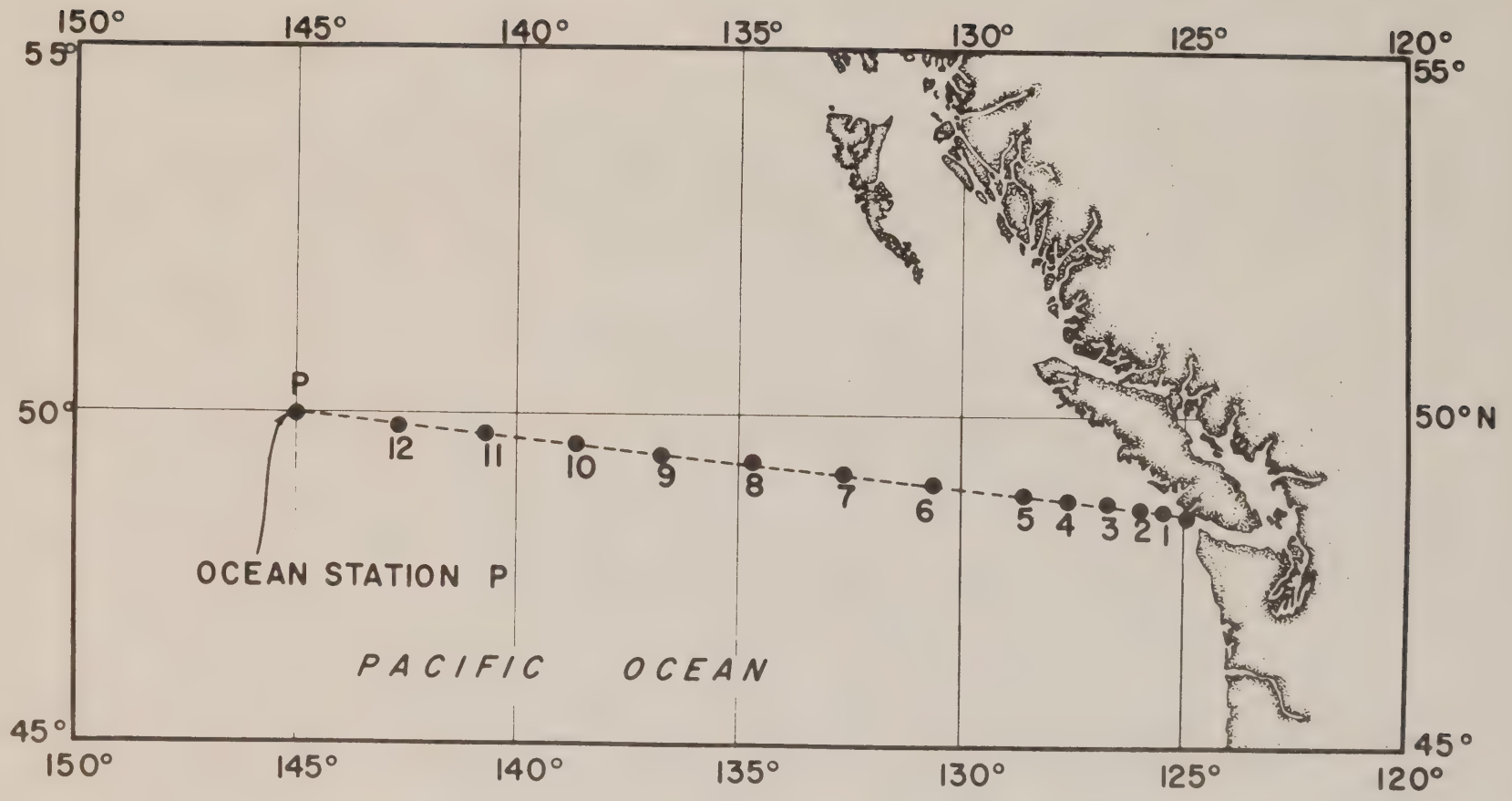


Fig. 1 Chart showing Line P station positions.

Oceanographic Data Obtained on Cruise P-78-4

(CODC Reference No. 15-78-004)

Results of Hydrographic Observations

(P-78-4)

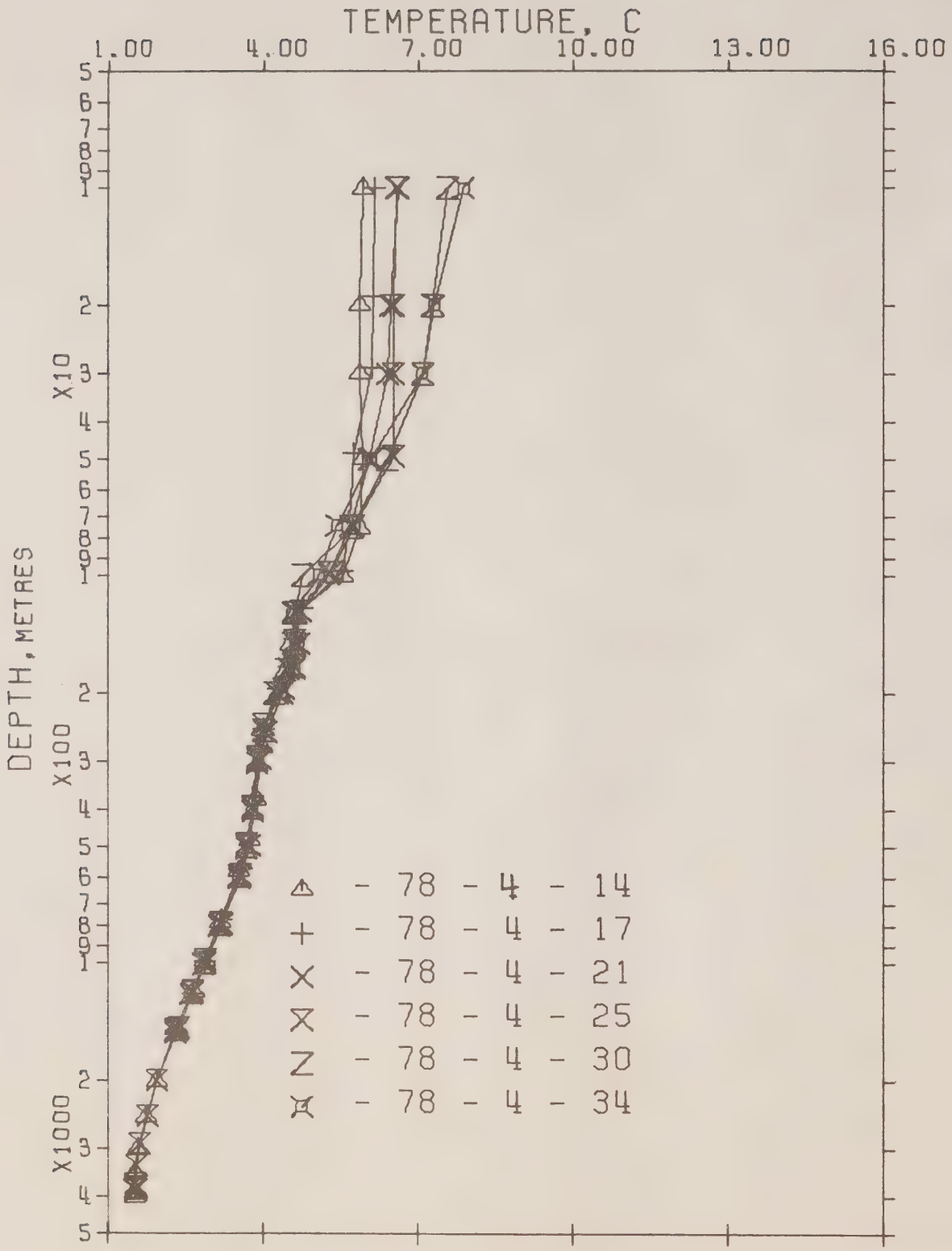


Figure 2. Composite plot of temperature vs $\log_{10}$ depth for Station P.

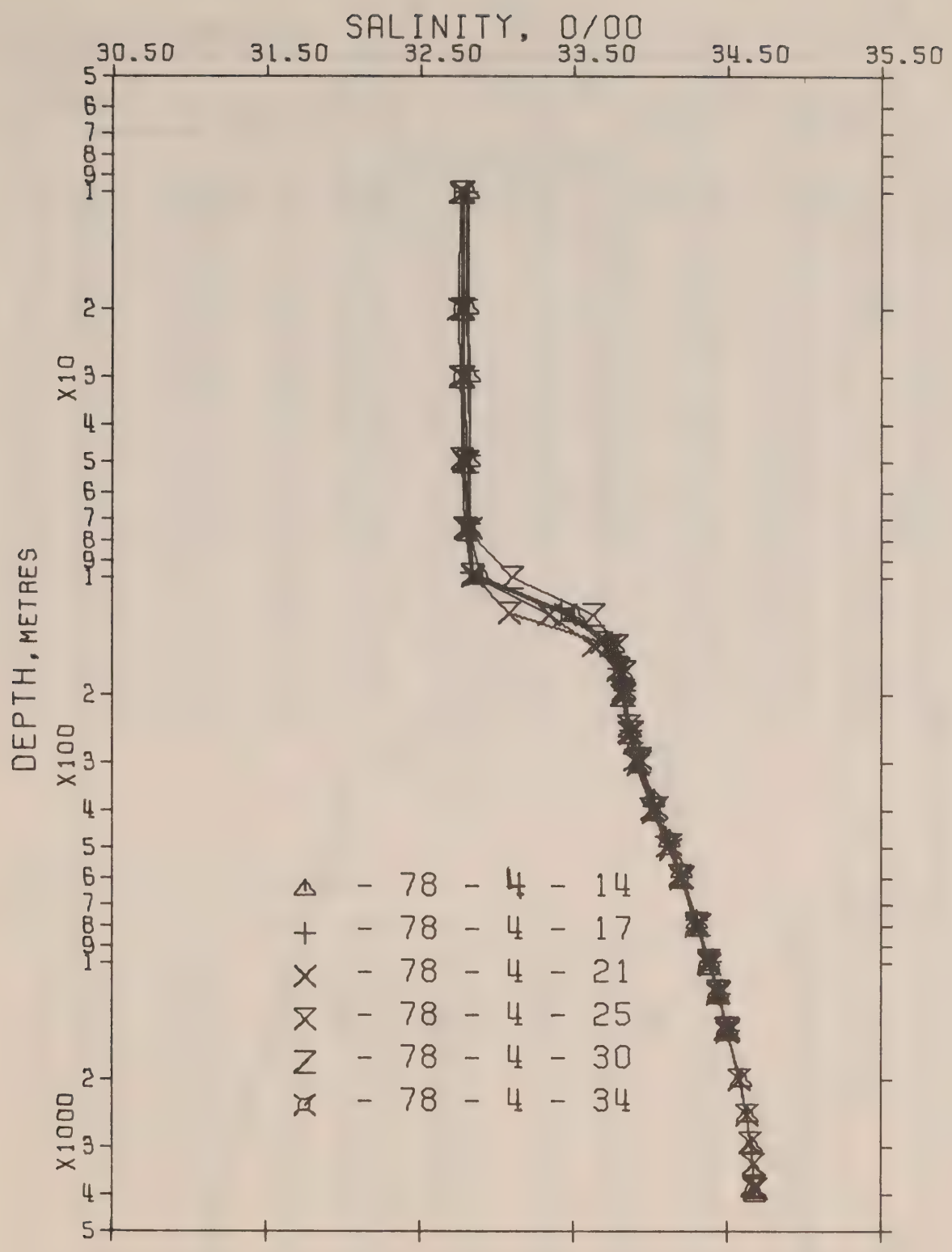
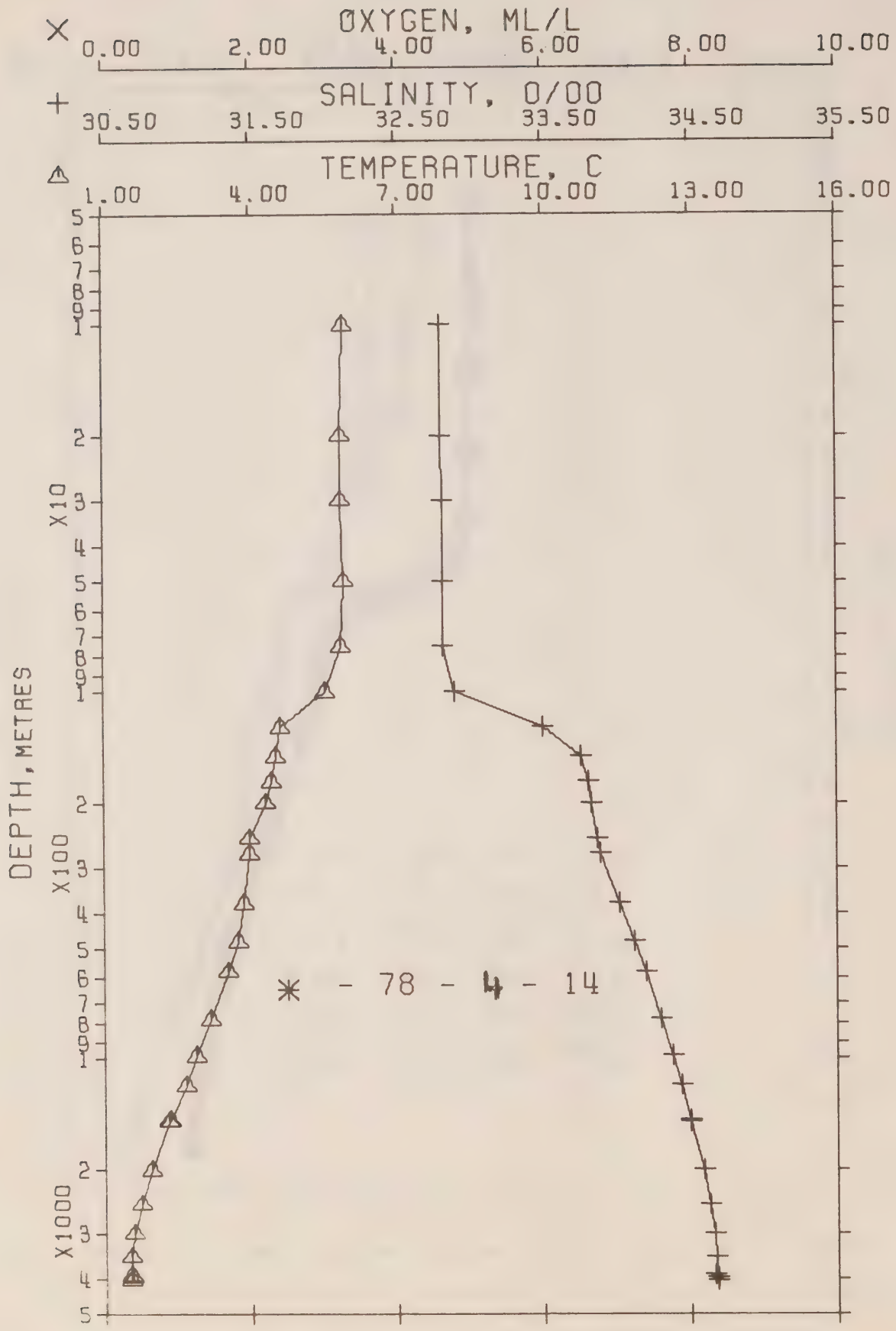


Figure 3. Composite plot of salinity vs $\log_{10}$ depth for Station P.

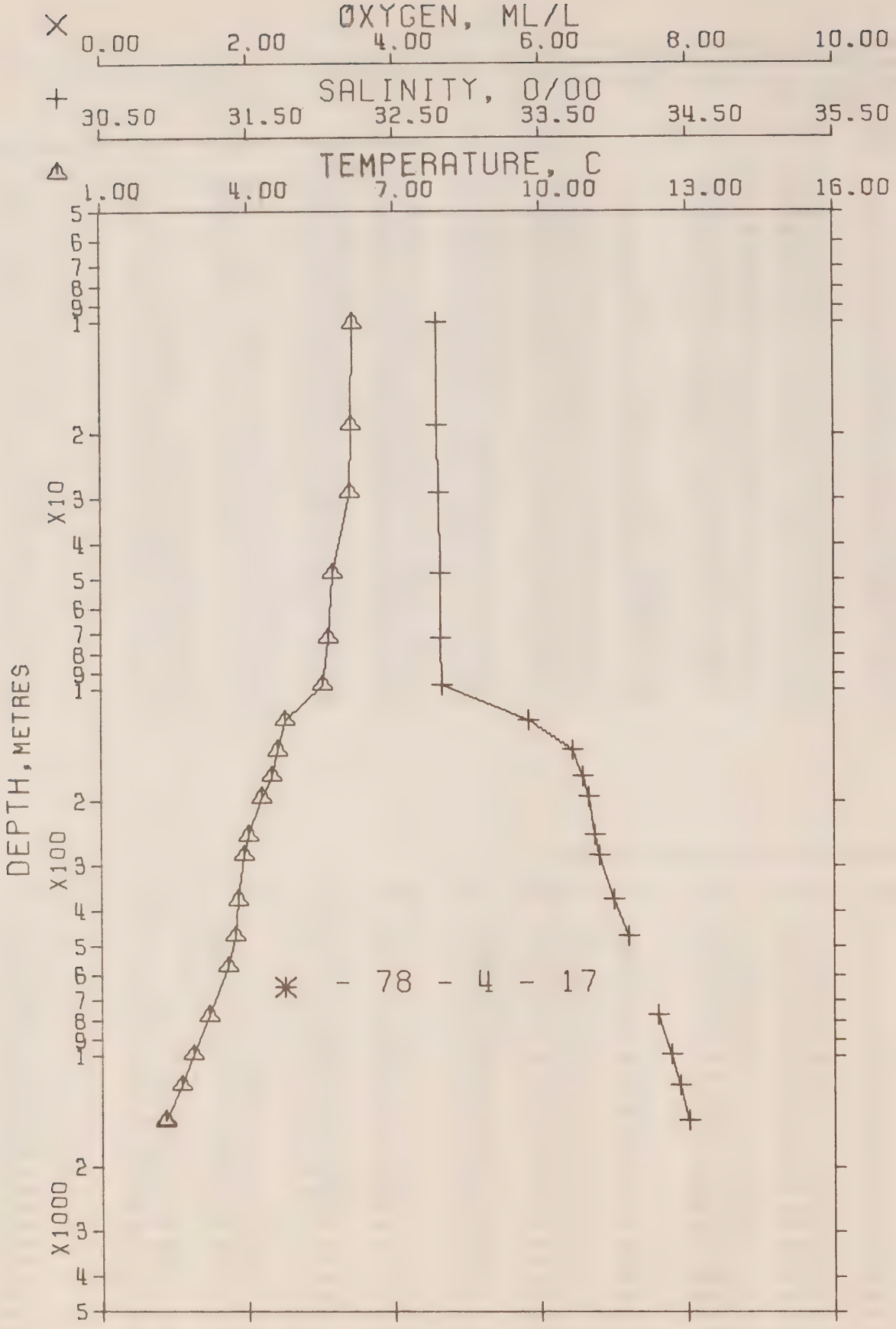

OXYGEN, ML/L
0.00
2.00
4.00
6.00
8.00
10.00
SALINITY, O/OO
30.50
31.50
32.50
33.50
34.50
35.50
TEMPERATURE, C
1.00
4.00
7.00
10.00
13.00
16.00
DEPTH, METRES
X10
X100
X1000
* - 78 - 4 - 14

OFFSHORE OCEANOGRAPHY GROUP
REFERENCE NO. 78- 4 - 14 DATE 10/ 5/78 GMT 18.2
POSITION 50- .0 N, 145- .0 W STATION P
OBSERVED DATA

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	THETA	SVA (THETA)	DELTA D	POT. EN	OXY	SOUND
0	6.20	32.813	0	25.825	218.2	6.20	218.2	.00	.00		1473.
10	5.92	32.814	10	25.861	214.9	5.92	214.8	.22	.01		1472.
20	5.87	32.815	20	25.868	214.4	5.87	214.1	.43	.04		1472.
30	5.86	32.822	30	25.875	213.8	5.86	213.5	.65	.10		1472.
50	5.92	32.819	50	25.865	215.0	5.92	214.4	1.08	.28		1473.
75	5.85	32.821	75	25.875	214.3	5.84	213.4	1.62	.62		1473.
101	5.54	32.896	100	25.971	205.4	5.53	204.2	2.15	1.10		1472.
126	4.60	33.504	125	26.558	149.8	4.59	148.5	2.60	1.61		1469.
151	4.51	33.761	150	26.771	129.8	4.50	128.3	2.95	2.11		1470.
176	4.41	33.815	175	26.825	124.9	4.40	123.2	3.27	2.64		1470.
201	4.29	33.830	200	26.849	122.8	4.28	120.8	3.58	3.24		1470.
252	3.98	33.875	250	26.917	116.6	3.96	114.4	4.18	4.63		1469.
278	3.98	33.893	276	26.931	115.5	3.96	113.0	4.49	5.46		1470.
380	3.84	34.016	377	27.043	105.7	3.81	102.3	5.61	9.22		1471.
482	3.72	34.125	478	27.142	97.1	3.69	92.9	6.65	13.75		1472.
583	3.52	34.203	578	27.223	90.0	3.48	85.1	7.59	18.87		1473.
786	3.15	34.305	779	27.339	79.9	3.10	74.0	9.31	30.84		1475.
990	2.87	34.382	980	27.426	72.4	2.80	65.7	10.86	44.81		1477.
1192	2.64	34.439	1180	27.492	66.9	2.56	59.4	12.26	60.48		1480.
1488	2.33	34.504	1472	27.570	60.1	2.23	51.9	14.13	85.89		1484.
1498	2.30	34.501	1482	27.570	60.1	2.20	51.9	14.19	86.82		1484.
2035	1.93	34.588	2010	27.669	51.6	1.79	42.2	17.19	140.71		1491.
2532	1.72	34.629	2498	27.718	47.7	1.54	37.4	19.64	197.80		1499.
3050	1.58	34.658	3005	27.752	45.3	1.35	33.9	22.04	266.10		1507.
3543	1.52	34.672	3487	27.767	44.8	1.25	32.1	24.26	340.54		1515.
3966	1.51	34.664	3900	27.762	46.3	1.19	32.4	26.21	415.36		1522.
4039	1.53	34.684	3971	27.776	45.4	1.20	30.9	26.54	428.99		1523.
4099	1.52	34.683	4030	27.776	45.5	1.19	30.9	26.82	440.38		1524.
4106	1.52	34.683	4036	27.776	45.5	1.18	30.9	26.85	441.55		1525.

INTERPOLATED TO STANDARD PRESSURE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	THETA	SVA (THETA)	DELTA D	POT. EN	OXY	SOUND
0	6.20	32.813	0	25.825	218.2	6.20	218.2	.00	.00		1473.
10	5.92	32.814	10	25.861	214.9	5.92	214.8	.22	.01		1472.
20	5.87	32.815	20	25.868	214.4	5.87	214.1	.43	.04		1472.
30	5.86	32.822	30	25.875	213.8	5.86	213.5	.65	.10		1472.
50	5.92	32.819	50	25.865	215.0	5.92	214.4	1.08	.28		1473.
75	5.85	32.821	75	25.875	214.3	5.84	213.4	1.62	.62		1473.
100	5.55	32.894	99	25.969	205.6	5.54	204.4	2.14	1.09		1472.
125	4.63	33.486	124	26.540	151.5	4.62	150.2	2.59	1.60		1469.
150	4.51	33.751	149	26.763	130.6	4.50	129.0	2.94	2.09		1470.
175	4.41	33.813	174	26.822	125.2	4.40	123.4	3.25	2.61		1470.
200	4.30	33.829	199	26.848	122.9	4.28	121.0	3.56	3.20		1470.
225	4.14	33.852	223	26.883	119.7	4.12	117.6	3.87	3.86		1470.
250	3.99	33.873	248	26.915	116.8	3.97	114.6	4.16	4.58		1469.
300	3.95	33.923	298	26.958	113.1	3.92	110.4	4.74	6.19		1470.
400	3.81	34.039	397	27.064	103.8	3.79	100.3	5.82	10.06		1471.
500	3.68	34.140	496	27.157	95.7	3.65	91.4	6.82	14.62		1473.
600	3.48	34.213	595	27.234	89.0	3.44	84.1	7.74	19.79		1473.
700	3.29	34.265	694	27.294	83.8	3.25	78.3	8.60	25.50		1474.
800	3.13	34.311	793	27.346	79.3	3.07	73.4	9.42	31.73		1475.
900	2.99	34.350	891	27.390	75.5	2.92	69.1	10.19	38.43		1476.
1000	2.86	34.385	990	27.430	72.1	2.79	65.4	10.93	45.57		1478.
1200	2.63	34.441	1188	27.494	66.7	2.55	59.2	12.32	61.11		1480.
1500	2.30	34.501	1483	27.570	60.0	2.20	51.8	14.20	86.96		1484.
2000	1.95	34.583	1976	27.664	52.1	1.81	42.8	17.01	136.97		1491.
2500	1.73	34.627	2467	27.715	48.0	1.55	37.7	19.49	193.87		1498.
3000	1.59	34.655	2956	27.749	45.5	1.37	34.2	21.82	259.15		1506.
3500	1.52	34.671	3445	27.766	44.9	1.25	32.3	24.07	333.66		1514.
4000	1.52	34.673	3933	27.768	45.9	1.20	31.7	26.37	421.71		1523.
4100	1.52	34.683	4031	27.776	45.5	1.19	30.9	26.82	440.48		1524.

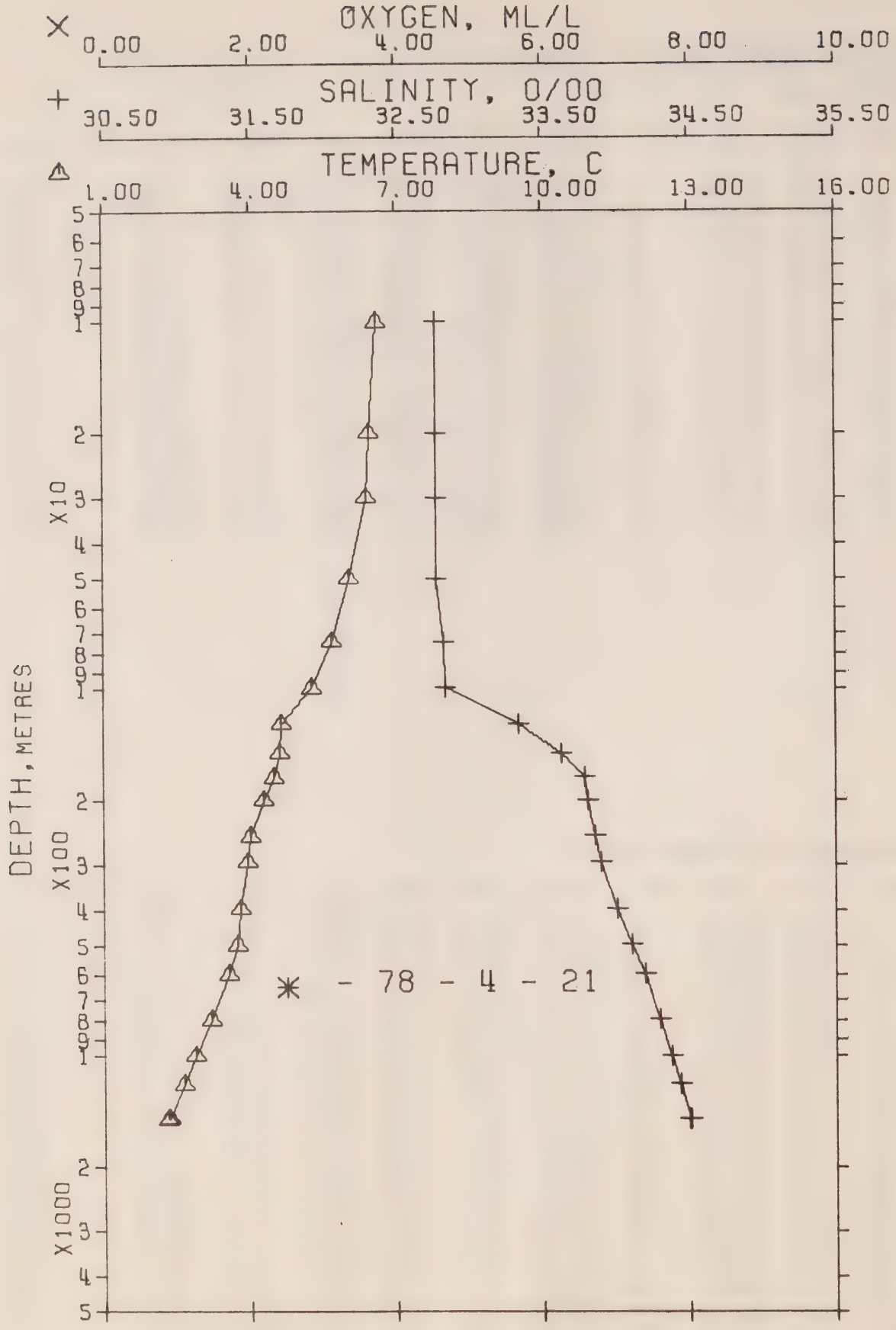

OXYGEN, ML/L
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6.00
8.00
10.00
SALINITY, O/OO
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31.50
32.50
33.50
34.50
35.50
TEMPERATURE, C
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4.00
7.00
10.00
13.00
16.00
DEPTH, METRES
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X100
X1000
* - 78 - 4 - 17

OFFSHORE OCEANOGRAPHY GROUP
REFERENCE NO. 78- 4- 17 DATE 15/ 5/78 GMT 18.3
POSITION 50- .0 N, 145- .0 W STATION P
OBSERVED DATA

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	THETA	SVA (THETA)	DELTA D	POT. EN	OXY	SOUND
0	6.14	32.806	0	25.827	218.0	6.14	218.0	.00	.00		1473.
10	6.15	32.804	10	25.825	218.4	6.15	218.2	.22	.01		1473.
19	6.14	32.804	19	25.826	218.3	6.14	218.1	.42	.04		1473.
29	6.10	32.806	29	25.832	217.8	6.10	217.5	.64	.09		1473.
48	5.75	32.816	48	25.883	213.2	5.75	212.6	1.05	.26		1472.
72	5.64	32.820	72	25.899	211.9	5.63	211.1	1.56	.57		1472.
98	5.53	32.831	97	25.921	210.1	5.52	209.0	2.11	1.05		1472.
122	4.74	33.424	121	26.479	157.2	4.73	156.0	2.55	1.54		1470.
147	4.60	33.717	146	26.726	134.0	4.59	132.5	2.92	2.04		1470.
172	4.48	33.792	171	26.799	127.4	4.47	125.6	3.24	2.58		1470.
197	4.28	33.826	196	26.847	122.9	4.27	121.0	3.56	3.17		1470.
251	4.00	33.874	249	26.914	116.9	3.98	114.6	4.20	4.63		1469.
284	3.92	33.896	282	26.940	114.7	3.90	112.2	4.58	5.68		1470.
376	3.80	34.003	373	27.037	106.2	3.77	102.9	5.60	9.09		1471.
472	3.72	34.104	468	27.125	98.6	3.69	94.5	6.58	13.32		1472.
572	3.57	34.179*	567	27.199	92.2	3.53	87.4	7.53	18.38		1473.
780	3.19	34.301	773	27.332	80.6	3.14	74.7	9.32	30.69		1475.
994	2.86	34.391	984	27.434	71.7	2.79	65.0	10.94	45.31		1477.
1208	2.61	34.449	1196	27.502	65.9	2.53	58.4	12.42	61.86		1480.
1508	2.30	34.513	1491	27.580	59.2	2.20	51.0	14.28	87.70		1484.

INTERPOLATED TO STANDARD PRESSURE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	THETA	SVA (THETA)	DELTA D	POT. EN	OXY	SOUND
0	6.14	32.806	0	25.827	218.0	6.14	218.0	.00	.00		1473.
10	6.15	32.804	10	25.825	218.4	6.15	218.2	.22	.01		1473.
20	6.14	32.804	20	25.827	218.3	6.13	218.0	.44	.04		1473.
30	6.08	32.807	30	25.835	217.6	6.08	217.2	.65	.10		1473.
50	5.74	32.816	50	25.884	213.1	5.74	212.5	1.08	.28		1472.
75	5.63	32.821	75	25.902	211.7	5.62	210.8	1.62	.61		1472.
100	5.44	32.895	99	25.981	204.4	5.44	203.3	2.16	1.10		1472.
125	4.72	33.464	124	26.513	154.0	4.71	152.8	2.60	1.60		1470.
150	4.58	33.727	149	26.736	133.2	4.57	131.6	2.96	2.10		1470.
175	4.46	33.796	174	26.805	126.8	4.44	125.1	3.28	2.64		1470.
200	4.26	33.829	199	26.851	122.6	4.25	120.7	3.59	3.23		1470.
225	4.13	33.852	223	26.884	119.6	4.11	117.5	3.89	3.89		1470.
250	4.00	33.873	248	26.913	117.0	3.99	114.7	4.19	4.60		1469.
300	3.90	33.917	298	26.959	113.1	3.88	110.4	4.77	6.22		1470.
400	3.78	34.031	397	27.061	104.1	3.75	100.6	5.85	10.08		1471.
500	3.67	34.127	496	27.147	96.6	3.64	92.4	6.85	14.68		1472.
600	3.51	34.198	595	27.220	90.4	3.47	85.4	7.79	19.92		1474.
700	3.32	34.259	694	27.286	84.6	3.27	79.1	8.66	25.70		1474.
800	3.16	34.310	793	27.343	79.6	3.10	73.7	9.48	31.97		1475.
900	3.00	34.354	891	27.393	75.3	2.93	68.9	10.25	38.68		1476.
1000	2.85	34.393	990	27.436	71.5	2.78	64.7	10.99	45.77		1478.
1200	2.62	34.447	1188	27.500	66.1	2.54	58.6	12.36	61.18		1480.
1500	2.31	34.512	1483	27.578	59.4	2.21	51.1	14.24	87.01		1484.

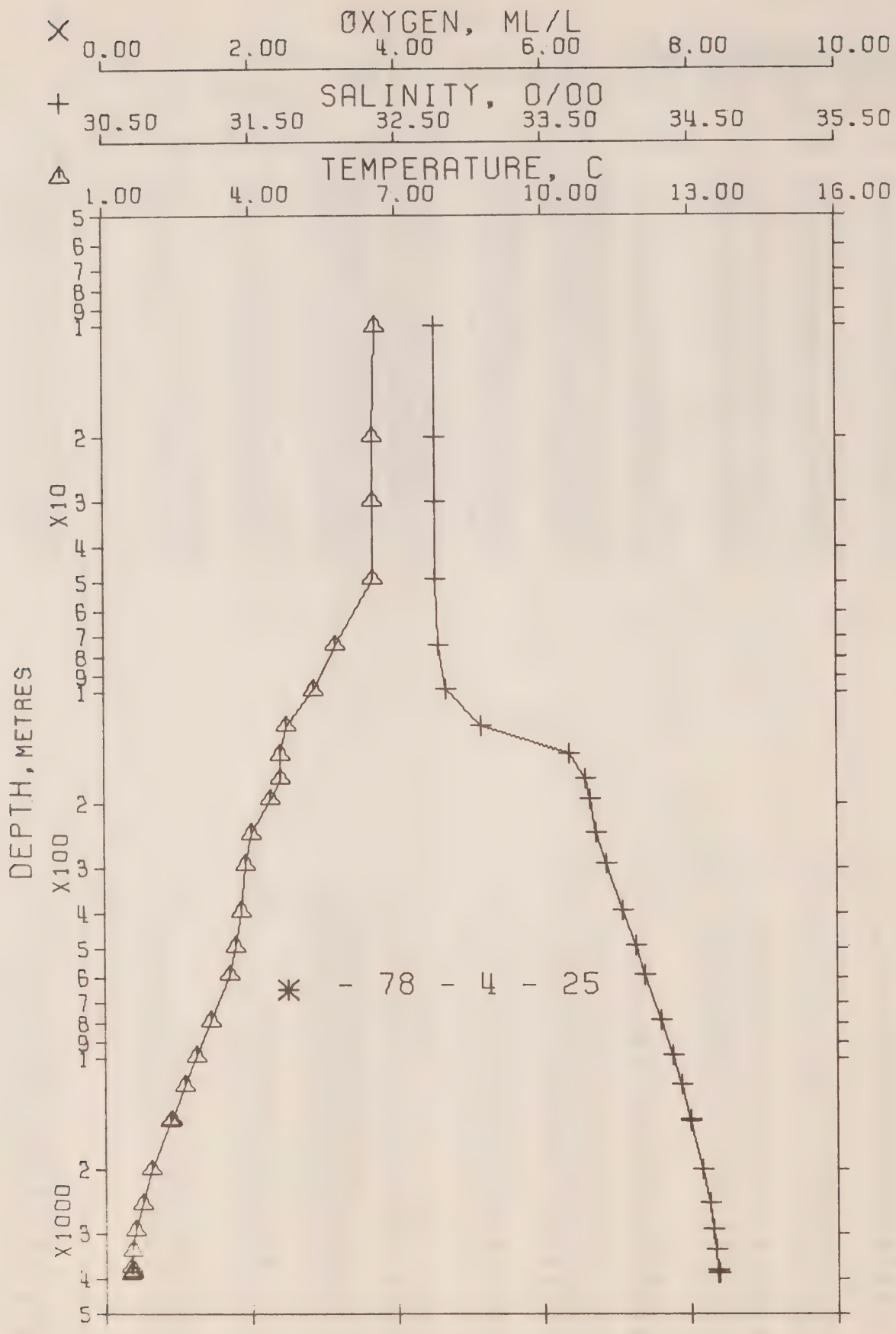

OXYGEN, ML/L
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4.00
6.00
8.00
10.00
SALINITY, O/OO
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31.50
32.50
33.50
34.50
35.50
TEMPERATURE, C
1.00
4.00
7.00
10.00
13.00
16.00
DEPTH, METRES
X10
X100
X1000
* - 78 - 4 - 21

OFFSHORE OCEANOGRAPHY GROUP
REFERENCE NO. 78- 4- 21 DATE 22/ 5/78 GMT 18.3
POSITION 50- .0 N, 145- .0 W STATION P
OBSERVED DATA

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	THETA	SVA (THETA)	DELTA D	POT. EN	OXY	SOUND
0	6.60	32.776	0	25.745	225.8	6.60	225.8	.00	.00		1475.
10	6.62	32.778	10	25.744	226.0	6.62	225.9	.23	.01		1475.
20	6.46	32.779	20	25.766	224.1	6.46	223.8	.45	.05		1474.
30	6.39	32.783	30	25.778	223.1	6.39	222.7	.68	.10		1474.
50	6.04	32.779	50	25.819	219.4	6.04	218.8	1.12	.29		1473.
74	5.67	32.827	74	25.901	211.7	5.66	210.9	1.65	.62		1472.
100	5.25	32.839	99	25.960	206.4	5.24	205.3	2.18	1.10		1471.
125	4.62	33.337	124	26.424	162.5	4.61	161.3	2.65	1.63		1469.
150	4.59	33.630	149	26.659	140.5	4.58	138.9	3.02	2.15		1470.
175	4.48	33.786	174	26.794	127.8	4.47	126.1	3.36	2.71		1470.
201	4.27	33.814	200	26.839	123.8	4.26	121.8	3.69	3.34		1470.
253	4.00	33.864	251	26.906	117.7	3.98	115.4	4.31	4.77		1469.
297	3.93	33.903	295	26.944	114.4	3.91	111.8	4.82	6.22		1470.
399	3.79	34.007	396	27.041	106.0	3.76	102.5	5.94	10.20		1471.
501	3.72	34.114	497	27.133	98.1	3.68	93.7	6.98	14.96		1473.
602	3.55	34.196	597	27.215	90.9	3.51	85.9	7.94	20.33		1474.
803	3.18	34.297	796	27.330	80.9	3.12	74.9	9.66	32.64		1476.
1004	2.85	34.381	994	27.427	72.4	2.78	65.6	11.19	46.73		1478.
1203	2.63	34.440	1191	27.494	66.8	2.55	59.2	12.58	62.29		1480.
1492	2.32	34.506	1476	27.572	59.9	2.22	51.6	14.35	86.64		1484.
1503	2.30	34.500	1486	27.569	60.2	2.20	51.9	14.41	87.57		1484.

INTERPOLATED TO STANDARD PRESSURE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	THETA	SVA (THETA)	DELTA D	POT. EN	OXY	SOUND
0	6.60	32.776	0	25.745	225.8	6.60	225.8	.00	.00		1475.
10	6.62	32.778	10	25.744	226.0	6.62	225.9	.23	.01		1475.
20	6.46	32.779	20	25.766	224.1	6.46	223.8	.45	.05		1474.
30	6.39	32.783	30	25.778	223.1	6.39	222.7	.68	.10		1474.
50	6.04	32.779	50	25.819	219.4	6.04	218.8	1.12	.29		1473.
75	5.66	32.827	75	25.903	211.6	5.65	210.7	1.66	.63		1472.
100	5.25	32.839	99	25.960	206.4	5.24	205.3	2.18	1.10		1471.
125	4.62	33.337	124	26.424	162.5	4.61	161.3	2.65	1.63		1469.
150	4.59	33.630	149	26.659	140.5	4.58	138.9	3.02	2.15		1470.
175	4.48	33.786	174	26.794	127.8	4.47	126.1	3.36	2.71		1470.
200	4.28	33.813	199	26.836	124.0	4.27	122.1	3.67	3.30		1470.
225	4.14	33.838	223	26.872	120.8	4.12	118.7	3.98	3.97		1470.
250	4.01	33.861	248	26.903	118.0	4.00	115.7	4.27	4.69		1469.
300	3.93	33.906	298	26.947	114.1	3.90	111.5	4.85	6.31		1470.
400	3.79	34.008	397	27.042	105.9	3.76	102.5	5.95	10.23		1471.
500	3.72	34.113	496	27.132	98.2	3.69	93.8	6.97	14.90		1473.
600	3.55	34.194	595	27.213	91.1	3.51	86.1	7.92	20.21		1474.
700	3.36	34.249	694	27.275	85.7	3.31	80.2	8.80	26.05		1475.
800	3.19	34.296	793	27.329	81.0	3.13	75.0	9.63	32.41		1476.
900	3.01	34.340	892	27.380	76.5	2.95	70.1	10.42	39.24		1477.
1000	2.86	34.380	990	27.426	72.5	2.79	65.8	11.17	46.46		1478.
1200	2.63	34.439	1188	27.493	66.8	2.55	59.3	12.55	62.02		1480.
1500	2.30	34.501	1484	27.570	60.1	2.20	51.9	14.40	87.34		1484.

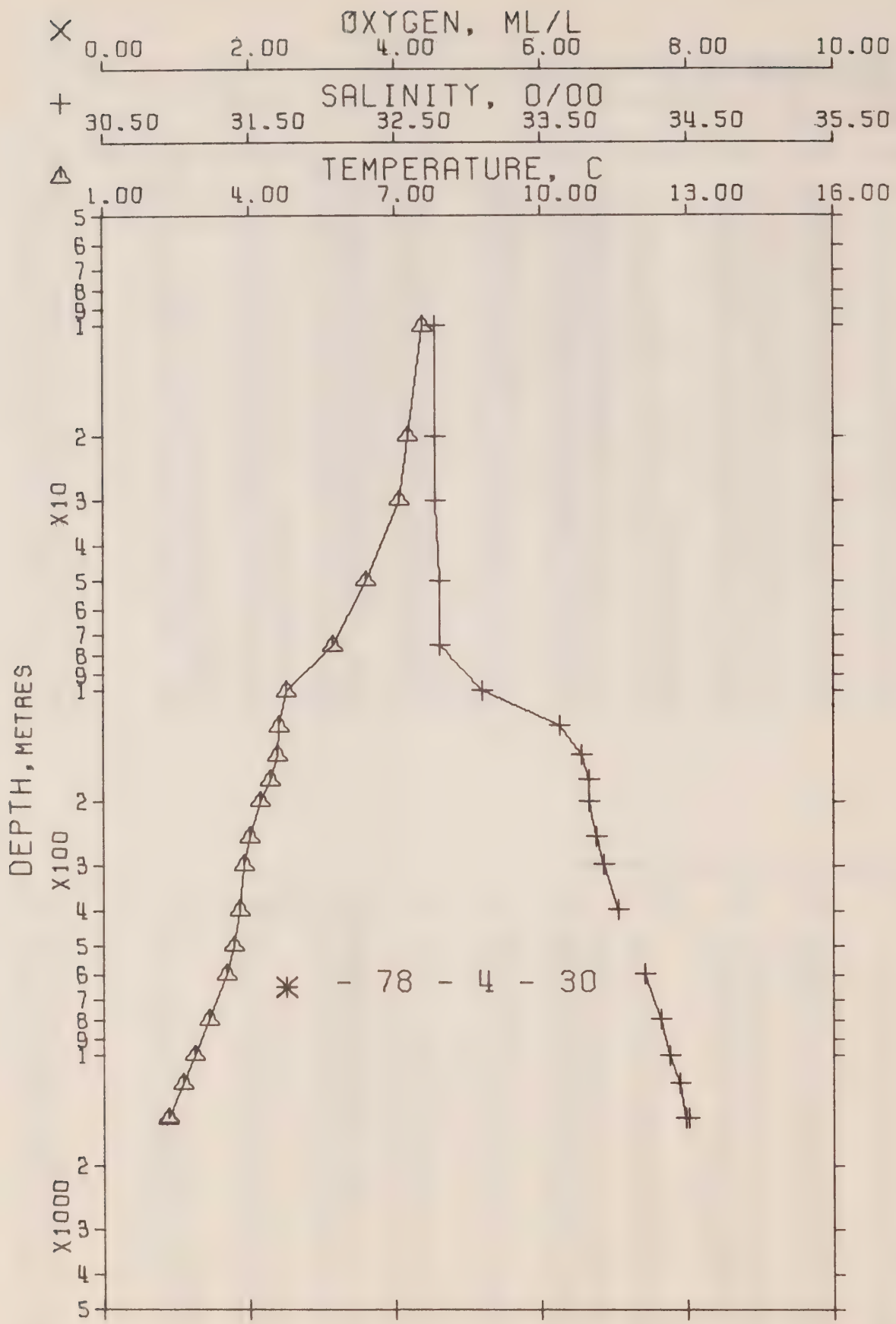

OXYGEN, ML/L
0.00
2.00
4.00
6.00
8.00
10.00
SALINITY, O/OO
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31.50
32.50
33.50
34.50
35.50
TEMPERATURE, C
1.00
4.00
7.00
10.00
13.00
16.00
DEPTH, METRES
X10
X100
X1000
* - 78 - 4 - 25

OFFSHORE OCEANOGRAPHY GROUP
REFERENCE NO. 78- 4- 25 DATE 29/ 5/78 GMT 18.3
POSITION 50- .0 N, 145- .0 W STATION P
OBSERVED DATA

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	THETA	SVA (THETA)	DELTA D	POT. EN	OXY	SOUND
0	6.54	32.767	0	25.746	225.7	6.54	225.7	.00	.00		1474.
10	6.58	32.766	10	25.740	226.4	6.58	226.3	.23	.01		1475.
20	6.52	32.766	20	25.748	225.8	6.52	225.5	.46	.05		1475.
30	6.53	32.766	30	25.747	226.0	6.53	225.6	.68	.10		1475.
49	6.52	32.770	49	25.751	225.9	6.52	225.2	1.12	.28		1475.
74	5.74	32.791	74	25.865	215.2	5.73	214.4	1.67	.63		1472.
99	5.30	32.841	98	25.956	206.8	5.29	205.7	2.19	1.09		1471.
124	4.73	33.079	123	26.208	183.0	4.72	181.8	2.68	1.64		1469.
148	4.60	33.679	147	26.696	136.9	4.59	135.4	3.06	2.17		1470.
172	4.60	33.787	171	26.782	129.0	4.59	127.2	3.38	2.70		1471.
196	4.38	33.822	195	26.833	124.3	4.37	122.3	3.69	3.27		1470.
244	4.00	33.864	242	26.906	117.6	3.98	115.4	4.26	4.56		1469.
296	3.89	33.932	294	26.971	111.8	3.87	109.2	4.86	6.21		1470.
397	3.79	34.036	394	27.064	103.8	3.76	100.3	5.95	10.05		1471.
496	3.68	34.132	492	27.151	96.3	3.65	92.0	6.94	14.54		1472.
595	3.54	34.194	590	27.214	90.9	3.50	86.0	7.86	19.69		1474.
793	3.17	34.302	786	27.335	80.4	3.12	74.4	9.55	31.63		1475.
992	2.87	34.379	982	27.424	72.7	2.80	65.9	11.07	45.38		1477.
1190	2.61	34.442	1178	27.497	66.3	2.53	58.9	12.44	60.67		1480.
1482	2.34	34.505	1466	27.570	60.2	2.24	51.9	14.30	85.89		1483.
1492	2.31	34.505	1476	27.572	59.9	2.21	51.6	14.36	86.82		1484.
2031	1.93	34.585	2006	27.667	51.8	1.79	42.5	17.37	140.76		1491.
2525	1.74	34.628	2491	27.716	48.0	1.56	37.6	19.82	197.68		1498.
2979	1.59	34.654	2936	27.748	45.6	1.37	34.3	21.93	256.92		1506.
3396	1.53	34.667	3344	27.763	44.9	1.27	32.7	23.82	318.21		1512.
3782	1.51	34.681*	3721	27.776	44.6	1.21	31.2	25.54	381.24		1519.
3856	1.54	34.684	3793	27.775	45.1	1.23	31.1	25.87	394.14		1520.
3922	1.53	34.686	3857	27.778	45.0	1.21	30.9	26.17	405.86		1521.
3929	1.51	34.682	3864	27.776	45.0	1.19	31.0	26.20	407.15		1521.

INTERPOLATED TO STANDARD PRESSURE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	THETA	SVA (THETA)	DELTA D	POT. EN	OXY	SOUND
0	6.54	32.767	0	25.746	225.7	6.54	225.7	.00	.00		1474.
10	6.58	32.766	10	25.740	226.4	6.58	226.3	.23	.01		1475.
20	6.52	32.766	20	25.748	225.8	6.52	225.5	.46	.05		1475.
30	6.53	32.766	30	25.747	226.0	6.53	225.6	.68	.10		1475.
50	6.49	32.771	50	25.755	225.5	6.49	224.8	1.13	.29		1475.
75	5.73	32.792	75	25.867	215.0	5.72	214.2	1.68	.64		1472.
100	5.27	32.855	99	25.971	205.3	5.26	204.3	2.21	1.11		1471.
125	4.72	33.111	124	26.233	180.5	4.71	179.3	2.70	1.67		1469.
150	4.60	33.669	149	26.704	136.2	4.59	134.6	3.09	2.21		1470.
175	4.57	33.791	174	26.788	128.4	4.56	126.6	3.42	2.76		1470.
200	4.35	33.826	199	26.839	123.7	4.33	121.7	3.73	3.36		1470.
225	4.14	33.848	223	26.879	120.1	4.12	118.0	4.04	4.02		1470.
250	3.99	33.873	248	26.915	116.8	3.97	114.6	4.33	4.74		1469.
300	3.89	33.936	298	26.975	111.5	3.86	108.8	4.90	6.34		1470.
400	3.79	34.039	397	27.067	103.6	3.76	100.1	5.98	10.17		1471.
500	3.67	34.135	496	27.154	96.0	3.64	91.8	6.98	14.73		1472.
600	3.53	34.197	595	27.218	90.6	3.49	85.7	7.91	19.96		1474.
700	3.33	34.255	694	27.283	84.9	3.28	79.4	8.78	25.77		1474.
800	3.16	34.305	793	27.339	80.1	3.10	74.1	9.61	32.07		1475.
900	3.00	34.346	891	27.385	76.0	2.94	69.6	10.39	38.82		1476.
1000	2.86	34.382	990	27.427	72.4	2.79	65.6	11.13	46.00		1478.
1200	2.60	34.444	1188	27.500	66.1	2.52	58.7	12.51	61.46		1480.
1500	2.30	34.506	1484	27.574	59.7	2.20	51.5	14.40	87.51		1484.
2000	1.95	34.581	1976	27.662	52.2	1.81	42.9	17.21	137.45		1491.
2500	1.75	34.626	2467	27.714	48.2	1.57	37.8	19.70	194.61		1498.
3000	1.59	34.655	2956	27.749	45.5	1.37	34.2	22.03	259.82		1506.
3500	1.52	34.671	3445	27.766	44.8	1.25	32.3	24.28	334.56		1514.

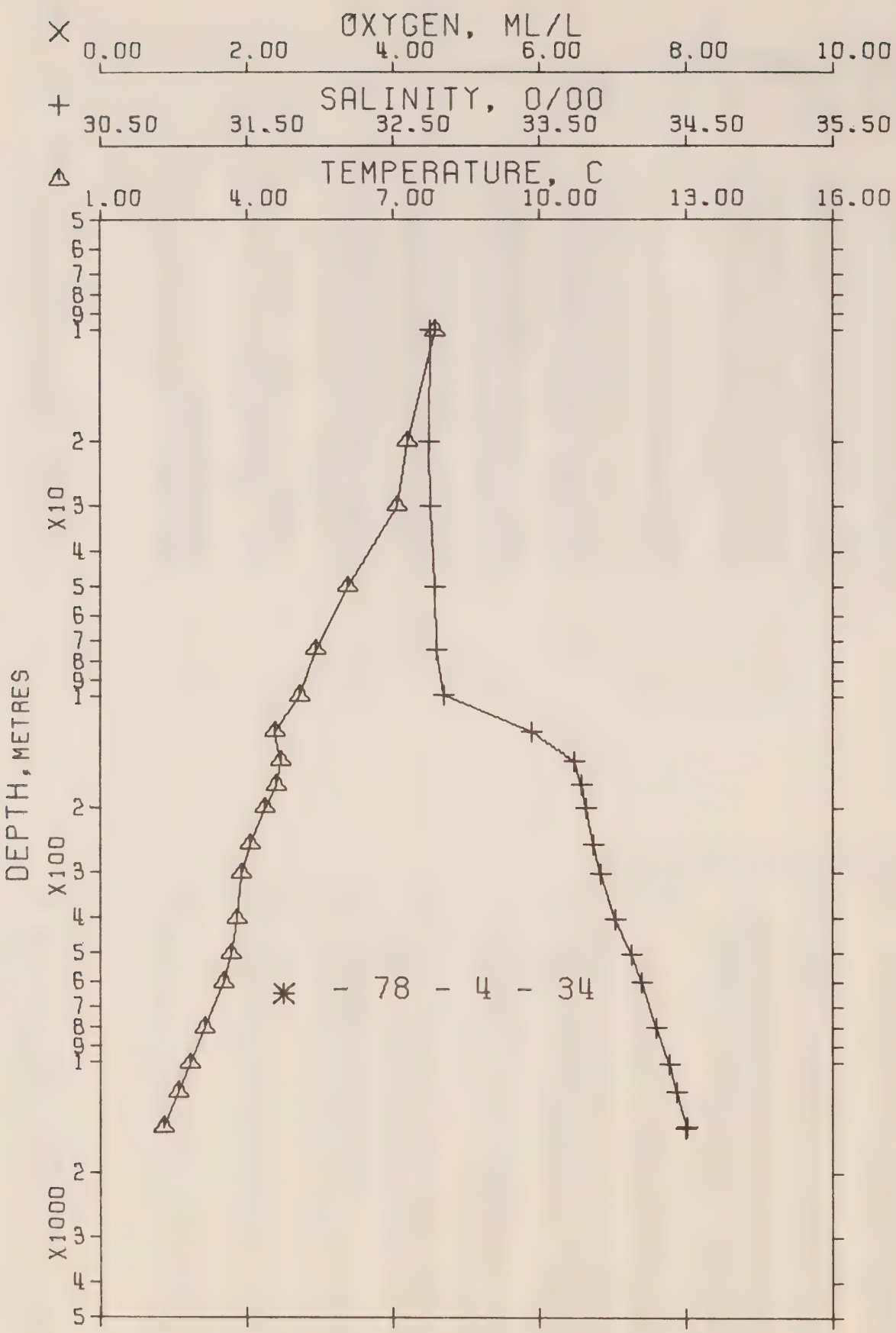

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SALINITY, O/OO
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TEMPERATURE, C
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DEPTH, METRES
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X100
X1000
* - 78 - 4 - 30

OFFSHORE OCEANOGRAPHY GROUP
REFERENCE NO. 78- 4- 30 DATE 6/ 6/78 GMT 17.9
POSITION 50- .0 N, 145- .0 W STATION P
OBSERVED DATA

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	THETA	SVA (THETA)	DELTA D	POT. EN	OXY	SOUND
0	8.23	32.784	0	25.525	246.7	8.23	246.7	.00	.00		1481.
10	7.58	32.783	10	25.618	238.0	7.58	237.9	.24	.01		1479.
20	7.26	32.783	20	25.663	233.9	7.26	233.6	.48	.05		1477.
30	7.08	32.783	30	25.687	231.7	7.08	231.3	.71	.11		1477.
50	6.39	32.806	50	25.796	221.6	6.39	220.9	1.17	.30		1475.
75	5.72	32.809	75	25.881	213.7	5.71	212.8	1.72	.65		1472.
101	4.74	33.102	100	26.225	181.2	4.73	180.2	2.22	1.10		1469.
126	4.60	33.632	125	26.659	140.2	4.59	138.9	2.63	1.56		1470.
151	4.57	33.783	150	26.782	128.8	4.56	127.2	2.96	2.03		1470.
176	4.42	33.826	175	26.832	124.2	4.41	122.5	3.28	2.56		1470.
201	4.21	33.835	200	26.862	121.6	4.20	119.7	3.59	3.16		1469.
253	3.99	33.878	251	26.918	116.5	3.97	114.2	4.20	4.57		1469.
301	3.89	33.931	299	26.971	111.9	3.87	109.3	4.75	6.13		1470.
401	3.80	34.029	398	27.057	104.5	3.77	101.0	5.83	10.00		1471.
502	3.68	34.132*	498	27.151	96.3	3.64	92.0	6.85	14.67		1473.
602	3.52	34.215	597	27.233	89.2	3.48	84.2	7.77	19.88		1474.
803	3.17	34.316	796	27.346	79.4	3.11	73.4	9.46	31.96		1476.
1004	2.87	34.380	994	27.425	72.7	2.80	65.9	10.98	45.95		1478.
1205	2.61	34.450	1193	27.503	65.8	2.53	58.3	12.38	61.67		1480.
1494	2.33	34.495	1478	27.563	60.8	2.23	52.6	14.32	88.63		1484.
1505	2.31	34.512	1488	27.578	59.4	2.21	51.1	14.38	89.57		1484.

INTERPOLATED TO STANDARD PRESSURE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	THETA	SVA (THETA)	DELTA D	POT. EN	OXY	SOUND
0	8.23	32.784	0	25.525	246.7	8.23	246.7	.00	.00		1481.
10	7.58	32.783	10	25.618	238.0	7.58	237.9	.24	.01		1479.
20	7.26	32.783	20	25.663	233.9	7.26	233.6	.48	.05		1477.
30	7.08	32.783	30	25.687	231.7	7.08	231.3	.71	.11		1477.
50	6.39	32.806	50	25.796	221.6	6.39	220.9	1.17	.30		1475.
75	5.72	32.809	75	25.881	213.7	5.71	212.8	1.72	.65		1472.
100	4.76	33.095	99	26.217	181.9	4.75	180.9	2.21	1.08		1469.
125	4.60	33.616	124	26.646	141.4	4.59	140.2	2.61	1.55		1470.
150	4.57	33.777	149	26.777	129.2	4.56	127.7	2.94	2.01		1470.
175	4.43	33.824	174	26.830	124.4	4.41	122.7	3.26	2.53		1470.
200	4.22	33.835	199	26.860	121.7	4.21	119.8	3.57	3.12		1469.
225	4.10	33.856	223	26.889	119.1	4.09	117.0	3.87	3.77		1469.
250	4.00	33.876	248	26.916	116.8	3.98	114.5	4.16	4.49		1469.
300	3.89	33.930	298	26.969	112.0	3.87	109.4	4.74	6.09		1470.
400	3.80	34.028	397	27.056	104.5	3.77	101.1	5.82	9.95		1471.
500	3.68	34.130	496	27.149	96.5	3.65	92.2	6.82	14.56		1473.
600	3.52	34.213	595	27.231	89.3	3.48	84.4	7.75	19.76		1474.
700	3.34	34.268	694	27.292	84.0	3.29	78.5	8.62	25.50		1475.
800	3.18	34.315	793	27.345	79.5	3.12	73.5	9.44	31.74		1476.
900	3.02	34.349	891	27.386	76.0	2.96	69.5	10.21	38.47		1477.
1000	2.88	34.379	990	27.423	72.8	2.81	66.0	10.96	45.67		1478.
1200	2.62	34.448	1188	27.501	66.0	2.54	58.5	12.34	61.23		1480.
1500	2.32	34.504	1483	27.571	60.0	2.22	51.8	14.36	89.15		1484.


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OXYGEN, ML/L
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SALINITY, O/OO
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32.50
33.50
34.50
35.50
TEMPERATURE, C
1.00
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7.00
10.00
13.00
16.00
DEPTH, METRES
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X100
X1000
* - 78 - 4 - 34

OFFSHORE OCEANOGRAPHY GROUP
REFERENCE NO. 78- 4- 34 DATE 12/ 6/78 GMT 18.1
POSITION 50- .0 N, 145- .0 W STATION P
OBSERVED DATA

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	THETA	SVA (THETA)	DELTA D	POT. EN	OXY	SOUND
0	7.86	32.754	0	25.556	243.8	7.86	243.8	.00	.00		1479.
10	7.88	32.756	10	25.554	244.1	7.88	243.9	.25	.01		1480.
20	7.31	32.754	20	25.633	236.7	7.31	236.4	.49	.05		1478.
30	7.08	32.758	30	25.668	233.6	7.08	233.1	.72	.11		1477.
50	6.08	32.789	50	25.822	219.1	6.08	218.5	1.18	.30		1473.
74	5.42	32.803	74	25.912	210.7	5.41	209.9	1.70	.63		1471.
100	5.07	32.852	99	25.991	203.4	5.06	202.4	2.23	1.10		1470.
125	4.57	33.452	124	26.520	153.3	4.56	152.1	2.68	1.61		1469.
150	4.69	33.739	149	26.734	133.4	4.68	131.8	3.04	2.12		1470.
175	4.60	33.795	174	26.788	128.4	4.59	126.6	3.37	2.66		1471.
201	4.36	33.824	200	26.837	124.0	4.35	122.0	3.70	3.29		1470.
254	4.06	33.874	252	26.908	117.6	4.04	115.2	4.33	4.76		1470.
305	3.89	33.917	303	26.959	113.0	3.87	110.3	4.92	6.45		1470.
406	3.79	34.022	403	27.053	104.9	3.76	101.4	6.02	10.43		1471.
507	3.68	34.128	503	27.148	96.7	3.64	92.3	7.04	15.16		1473.
608	3.51	34.202	603	27.223	90.1	3.47	85.1	7.98	20.52		1474.
810	3.14	34.305	803	27.340	79.9	3.08	73.9	9.70	32.88		1476.
1013	2.84	34.386	1003	27.432	72.0	2.77	65.1	11.23	47.11		1478.
1217	2.59	34.445	1204	27.501	66.0	2.51	58.5	12.63	63.03		1480.
1515	2.29	34.510	1498	27.578	59.4	2.19	51.1	14.49	88.96		1484.
1525	2.28	34.500+	1508	27.571	60.0	2.18	51.8	14.55	89.89		1484.

INTERPOLATED TO STANDARD PRESSURE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	THETA	SVA (THETA)	DELTA D	POT. EN	OXY	SOUND
0	7.86	32.754	0	25.556	243.8	7.86	243.8	.00	.00		1479.
10	7.88	32.756	10	25.554	244.1	7.88	243.9	.25	.01		1480.
20	7.31	32.754	20	25.633	236.7	7.31	236.4	.49	.05		1478.
30	7.08	32.758	30	25.668	233.6	7.08	233.1	.72	.11		1477.
50	6.08	32.789	50	25.822	219.1	6.08	218.5	1.18	.30		1473.
75	5.41	32.804	75	25.914	210.5	5.41	209.7	1.71	.63		1471.
100	5.07	32.852	99	25.991	203.4	5.06	202.4	2.23	1.10		1470.
125	4.57	33.452	124	26.520	153.3	4.56	152.1	2.68	1.61		1469.
150	4.69	33.739	149	26.734	133.4	4.68	131.8	3.04	2.12		1470.
175	4.60	33.795	174	26.788	128.4	4.59	126.6	3.37	2.66		1471.
200	4.37	33.823	199	26.835	124.2	4.36	122.2	3.68	3.26		1470.
225	4.22	33.848	223	26.871	120.9	4.20	118.7	3.99	3.92		1470.
250	4.08	33.871	248	26.903	118.0	4.06	115.7	4.28	4.64		1470.
300	3.91	33.913	298	26.955	113.4	3.89	110.8	4.86	6.26		1470.
400	3.80	34.016	397	27.048	105.4	3.77	101.9	5.96	10.16		1471.
500	3.69	34.121	496	27.142	97.2	3.65	92.9	6.97	14.80		1473.
600	3.52	34.196	595	27.218	90.6	3.48	85.7	7.91	20.06		1474.
700	3.33	34.252	694	27.281	85.1	3.28	79.6	8.78	25.87		1474.
800	3.16	34.300	793	27.335	80.4	3.10	74.4	9.61	32.19		1475.
900	3.00	34.343	891	27.384	76.2	2.94	69.8	10.39	38.97		1476.
1000	2.86	34.381	990	27.427	72.4	2.79	65.7	11.14	46.16		1478.
1200	2.61	34.441	1188	27.496	66.5	2.53	59.0	12.52	61.69		1480.
1500	2.30	34.507	1484	27.575	59.7	2.20	51.4	14.41	87.61		1484.

Results of STP Observations

(P-78-4)

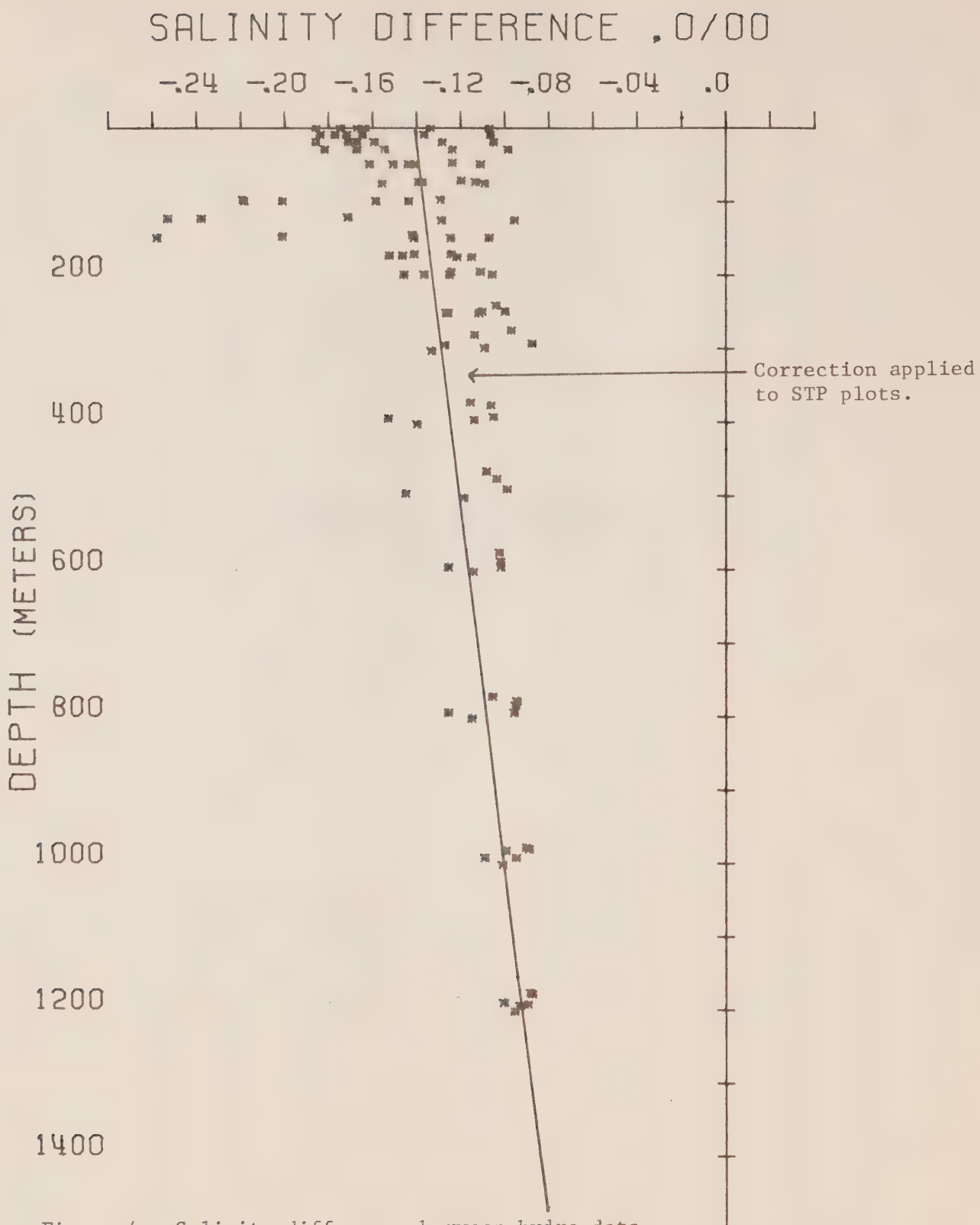


Figure 4. Salinity difference berween hydro data and STP.

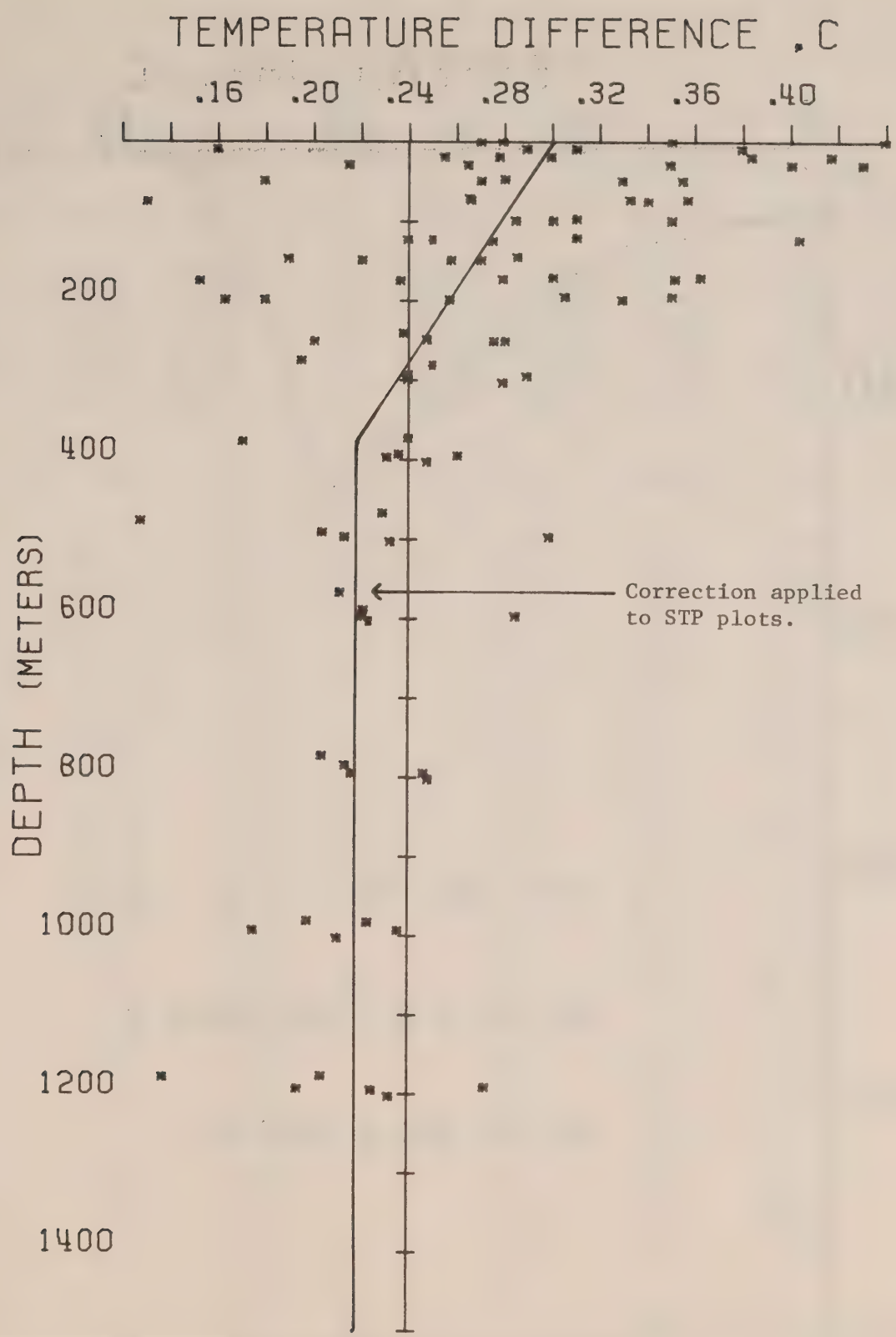
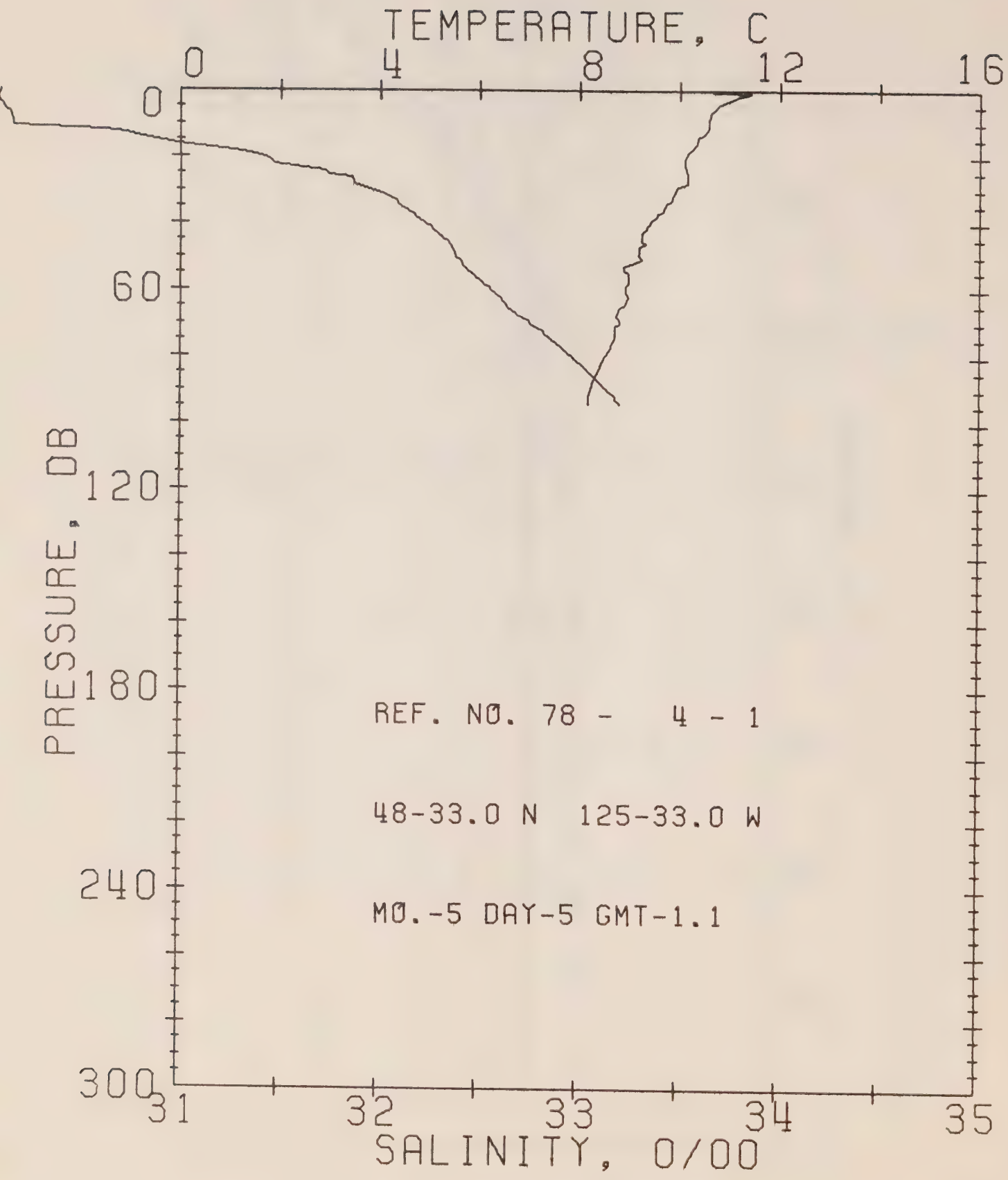


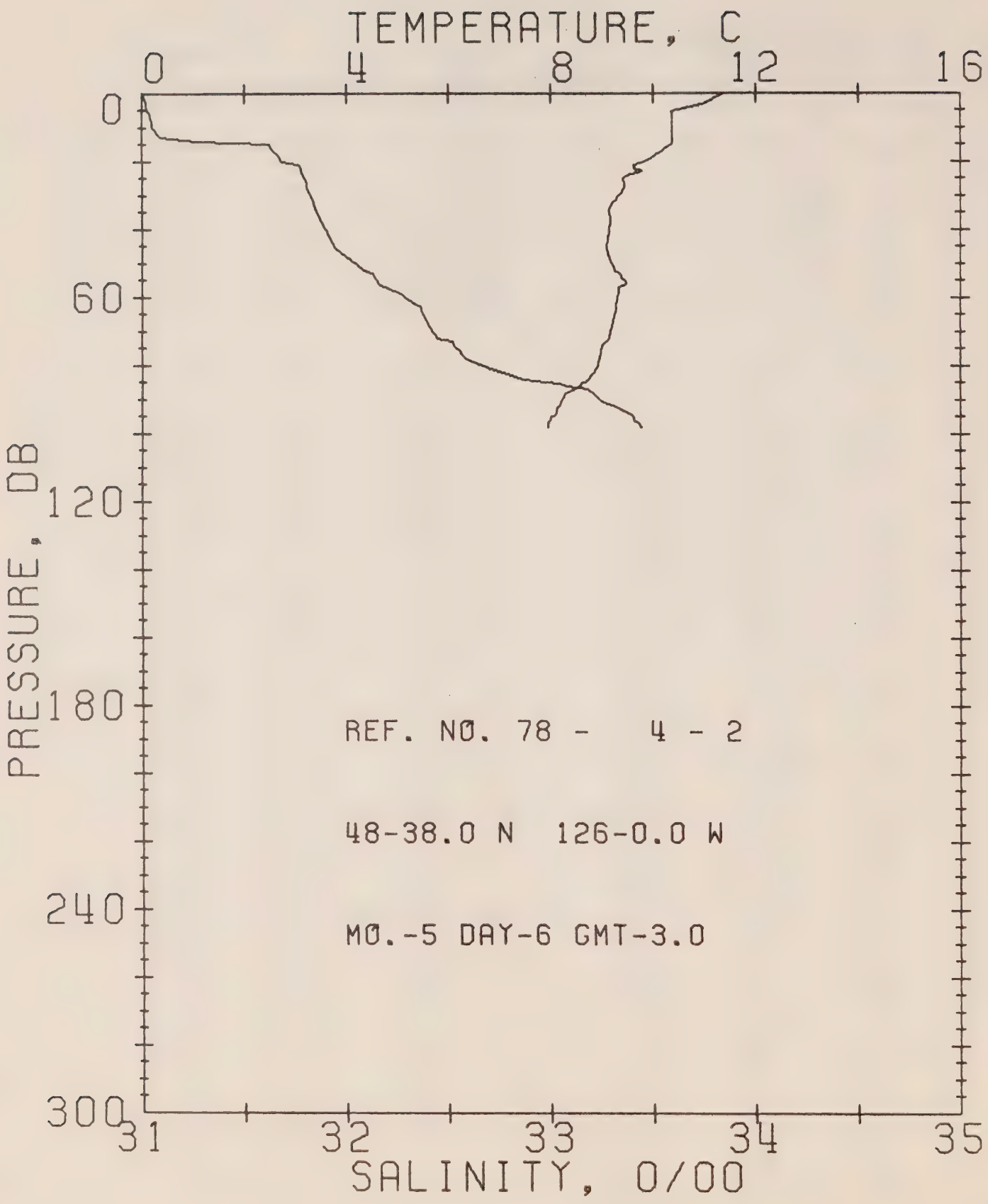
Figure 5. Temperature difference between hydro data and STP.


TEMPERATURE, C
0
4
8
12
16
0
60
120
180
240
300
PRESSURE, DB
REF. NØ. 78 - 4 - 1
48-33.0 N 125-33.0 W
MØ.-5 DAY-5 GMT-1.1
31
32
33
34
35
SALINITY, 0/00

OFFSHORE OCEANOGRAPHY GROUP
REFERENCE NO. 78- 4- 1 DATE 5/ 5/78 STATION 1
POSITION 48-33.0N, 125-33.0W GMT 1.1
RESULTS OF STP CAST 69 POINTS TAKEN FROM ANALOG TRACE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	DELTA D	POT. EN	SOUND
0	10.40	30.10	0	23.09	478.5	0.0	0.0	1486.
10	10.59	30.16	10	23.11	477.4	0.48	0.02	1487.
20	10.12	31.43	20	24.17	376.0	0.90	0.09	1487.
30	9.93	31.96	30	24.62	333.9	1.26	0.18	1487.
50	9.20	32.38	50	25.06	291.9	1.88	0.43	1485.
75	8.69	32.87	75	25.52	248.5	2.55	0.86	1484.

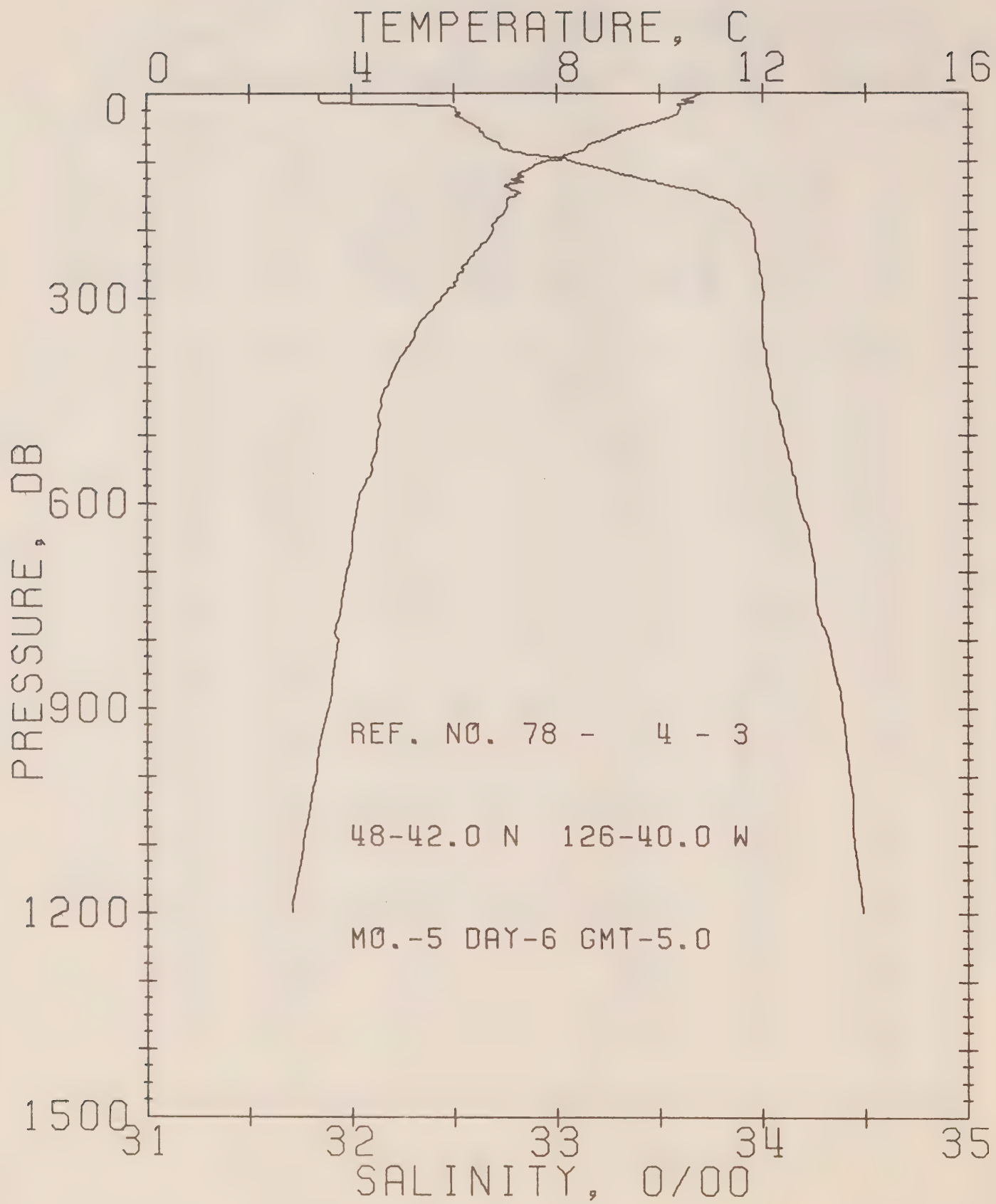
DEPTH	TEMP	SAL	DEPTH	TEMP	SAL
0.	10.40	30.10	47.	9.20	32.36
1.	11.41	30.10	50.	9.20	32.38
2.	11.12	30.09	51.	9.25	32.40
3.	11.02	30.09	53.	8.89	32.42
4.	10.79	30.10	54.	8.90	32.44
6.	10.67	30.13	55.	8.99	32.46
7.	10.60	30.15	58.	8.99	32.52
10.	10.59	30.16	59.	8.93	32.55
11.	10.58	30.16	60.	8.92	32.56
12.	10.55	30.62	61.	8.93	32.58
13.	10.50	30.72	62.	8.99	32.60
14.	10.38	30.81	64.	8.93	32.63
16.	10.34	30.98	65.	8.83	32.64
18.	10.21	31.27	66.	8.79	32.66
19.	10.16	31.35	67.	8.77	32.68
20.	10.12	31.43	68.	8.76	32.71
21.	10.10	31.45	69.	8.80	32.74
22.	10.11	31.47	70.	8.79	32.75
24.	10.13	31.72	71.	8.73	32.78
25.	10.15	31.74	72.	8.71	32.82
26.	10.16	31.86	73.	8.71	32.82
28.	10.17	31.87	74.	8.72	32.85
29.	9.97	31.91	76.	8.67	32.89
31.	9.89	32.01	77.	8.65	32.91
33.	9.83	32.08	78.	8.62	32.93
34.	9.74	32.09	80.	8.51	32.97
36.	9.69	32.14	83.	8.44	33.02
37.	9.57	32.17	84.	8.39	33.04
38.	9.52	32.18	87.	8.30	33.09
39.	9.46	32.20	90.	8.25	33.14
41.	9.36	32.25	91.	8.22	33.16
42.	9.30	32.27	92.	8.20	33.18
43.	9.25	32.29	93.	8.18	33.18
45.	9.26	32.34	94.	8.18	33.20
46.	9.33	32.35			


TEMPERATURE, C
0
4
8
12
16
0
60
120
180
240
300
PRESSURE, DB
REF. NO. 78 - 4 - 2
48-38.0 N 126-0.0 W
MO.-5 DAY-6 GMT-3.0
31
32
33
34
35
SALINITY, O/OO

OFFSHORE OCEANOGRAPHY GROUP
REFERENCE NO. 78- 4- 2 DATE 6/ 5/78 STATION 2
POSITION 48-38.0N, 126- 0.0W GMT 3.0
RESULTS OF STP CAST 57 POINTS TAKEN FROM ANALOG TRACE

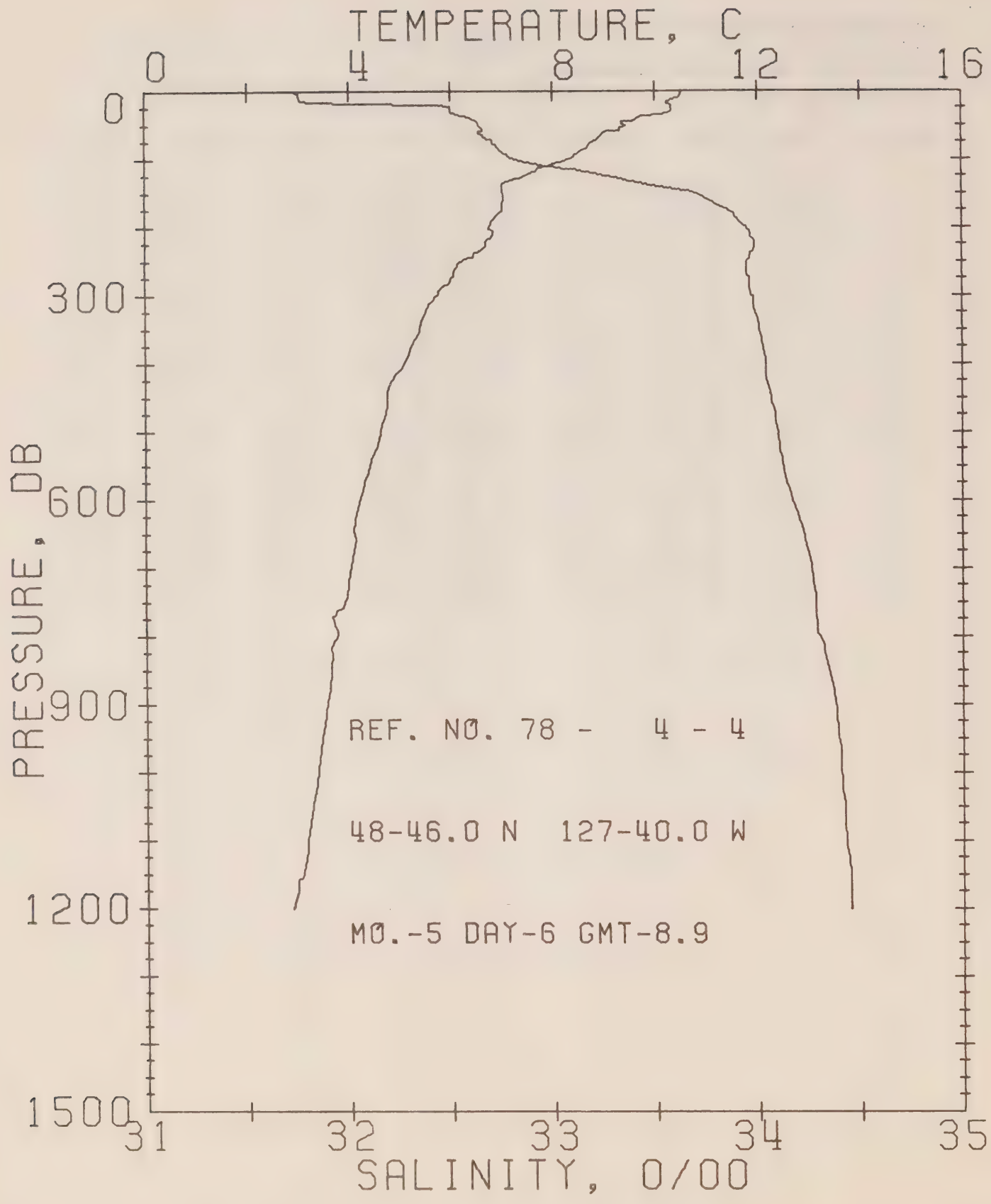
PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	DELTA D	POT. EN	SOUND
0	11.35	31.01	0	23.64	426.6	0.0	0.0	1490.
10	10.37	31.05	10	23.84	408.0	0.41	0.02	1497.
20	9.84	31.68	20	24.41	353.0	0.79	0.08	1486.
30	9.34	31.82	30	24.61	334.8	1.13	0.16	1484.
50	9.17	32.04	50	24.80	316.5	1.79	0.43	1484.
75	9.00	32.54	75	25.22	277.1	2.53	0.90	1485.

DEPTH	TEMP	SAL	DEPTH	TEMP	SAL
0.	11.35	31.01	53.	9.34	32.13
1.	11.24	31.01	55.	9.43	32.15
3.	11.04	31.02	56.	9.48	32.16
4.	10.71	31.02	57.	9.33	32.19
5.	10.35	31.03	59.	9.34	32.27
6.	10.36	31.04	60.	9.32	32.29
10.	10.37	31.05	63.	9.27	32.37
13.	10.37	31.09	64.	9.27	32.37
14.	10.37	31.27	69.	9.21	32.41
15.	10.37	31.62	72.	9.15	32.45
16.	10.25	31.63	73.	9.08	32.52
17.	10.19	31.64	74.	9.02	32.53
18.	10.05	31.66	78.	8.95	32.59
20.	9.84	31.68	81.	8.90	32.71
21.	9.64	31.77	84.	8.74	32.87
22.	9.64	31.78	85.	8.62	33.04
23.	9.78	31.78	86.	8.59	33.08
24.	9.48	31.79	87.	8.46	33.18
25.	9.42	31.80	88.	8.29	33.21
27.	9.44	31.81	90.	8.25	33.24
28.	9.45	31.81	91.	8.22	33.26
32.	9.23	31.84	92.	8.17	33.32
34.	9.14	31.85	93.	8.14	33.34
38.	9.16	31.88	94.	8.11	33.39
40.	9.15	31.90	95.	8.00	33.41
41.	9.14	31.91	96.	7.99	33.41
45.	9.09	31.94	97.	7.96	33.43
49.	9.14	32.02	98.	7.95	33.44
52.	9.24	32.09			


TEMPERATURE, C
0
4
8
12
16
0
300
600
900
1200
1500
PRESSURE, DB
REF. NO. 78 - 4 - 3
48-42.0 N 126-40.0 W
MO.-5 DAY-6 GMT-5.0
31
32
33
34
35
SALINITY, O/OO

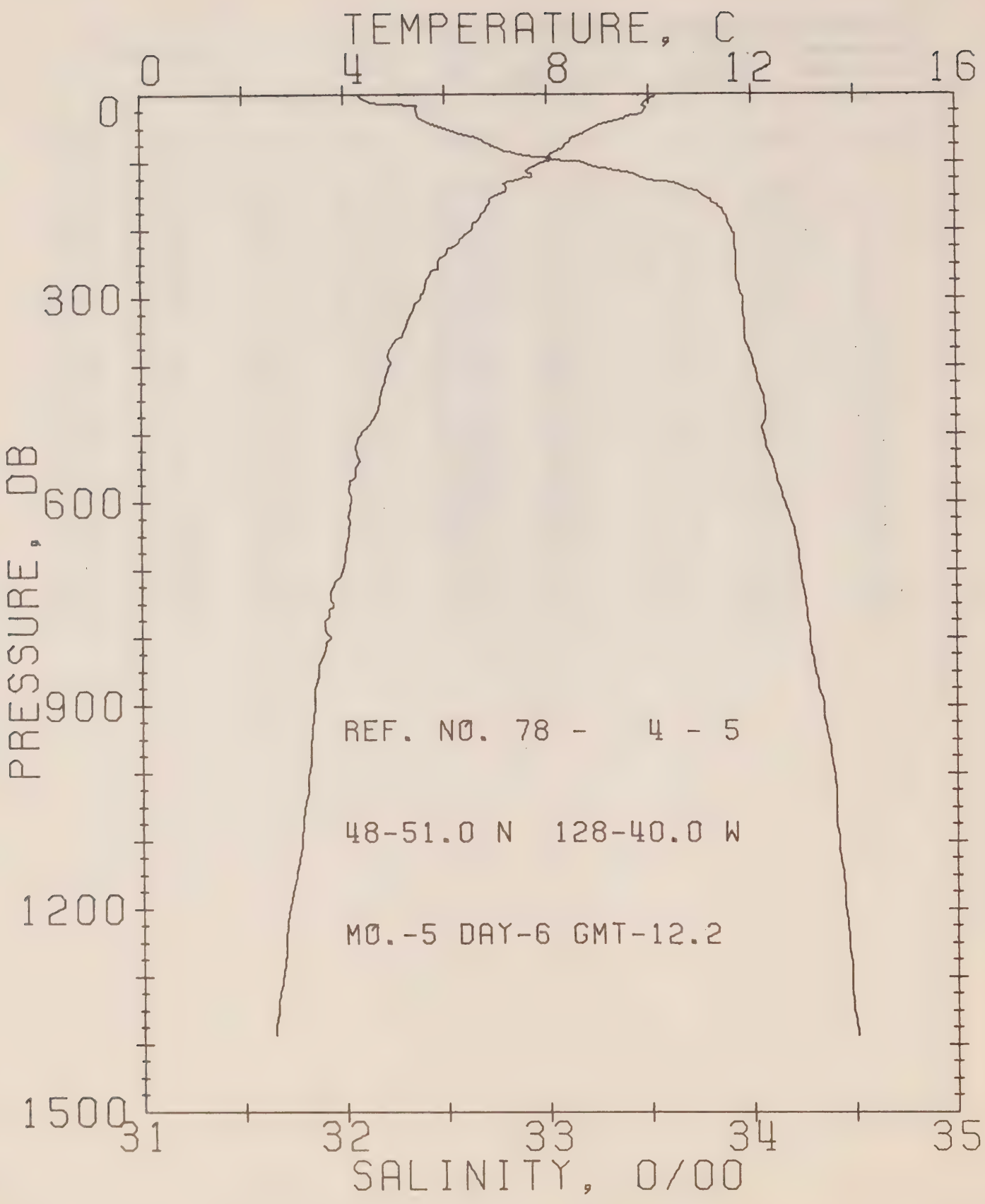
OFFSHORE OCEANOGRAPHY GROUP
REFERENCE NO. 78- 4- 3 DATE 5/ 5/78 STATION 3
POSITION 48-42.0N, 126-40.0W GMT 5.0
RESULTS OF STP CAST 233 POINTS TAKEN FROM ANALOG TRACE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	DELTA D	POT. EN	SOUND
0	10.79	31.84	0	24.38	355.8	0.0	0.0	1489.
10	10.44	31.84	10	24.44	350.5	0.35	0.02	1488.
20	10.40	32.49	20	24.96	301.6	0.69	0.07	1489.
30	10.35	32.53	30	24.99	298.4	0.99	0.15	1489.
50	9.54	32.61	50	25.19	279.7	1.57	0.38	1486.
75	8.65	32.72	75	25.41	258.9	2.24	0.81	1484.
100	7.77	33.08	99	25.82	220.0	2.85	1.35	1481.
125	7.17	33.41	124	26.17	187.4	3.36	1.93	1480.
150	7.23	33.73	149	26.41	165.0	3.80	2.54	1481.
175	6.96	33.90	174	26.58	149.1	4.18	3.18	1480.
200	6.74	33.96	199	26.66	142.1	4.55	3.88	1480.
225	6.47	33.97	223	26.70	138.2	4.90	4.64	1479.
250	6.24	33.99	248	26.75	134.1	5.24	5.46	1479.
300	5.75	34.01	298	26.83	127.1	5.89	7.30	1478.
400	4.85	34.02	397	26.94	116.5	7.12	11.64	1476.
500	4.50	34.10	496	27.04	107.5	8.23	16.75	1476.
600	4.10	34.18	595	27.15	98.3	9.26	22.53	1476.
800	3.73	34.32	793	27.30	85.1	11.09	35.56	1478.
1000	3.28	34.43	991	27.43	73.8	12.67	50.00	1479.


TEMPERATURE, C
0
4
8
12
16
0
300
600
900
1200
1500
PRESSURE, DB
REF. NO. 78 - 4 - 4
48-46.0 N 127-40.0 W
MO.-5 DAY-6 GMT-8.9
31
32
33
34
35
SALINITY, O/OO

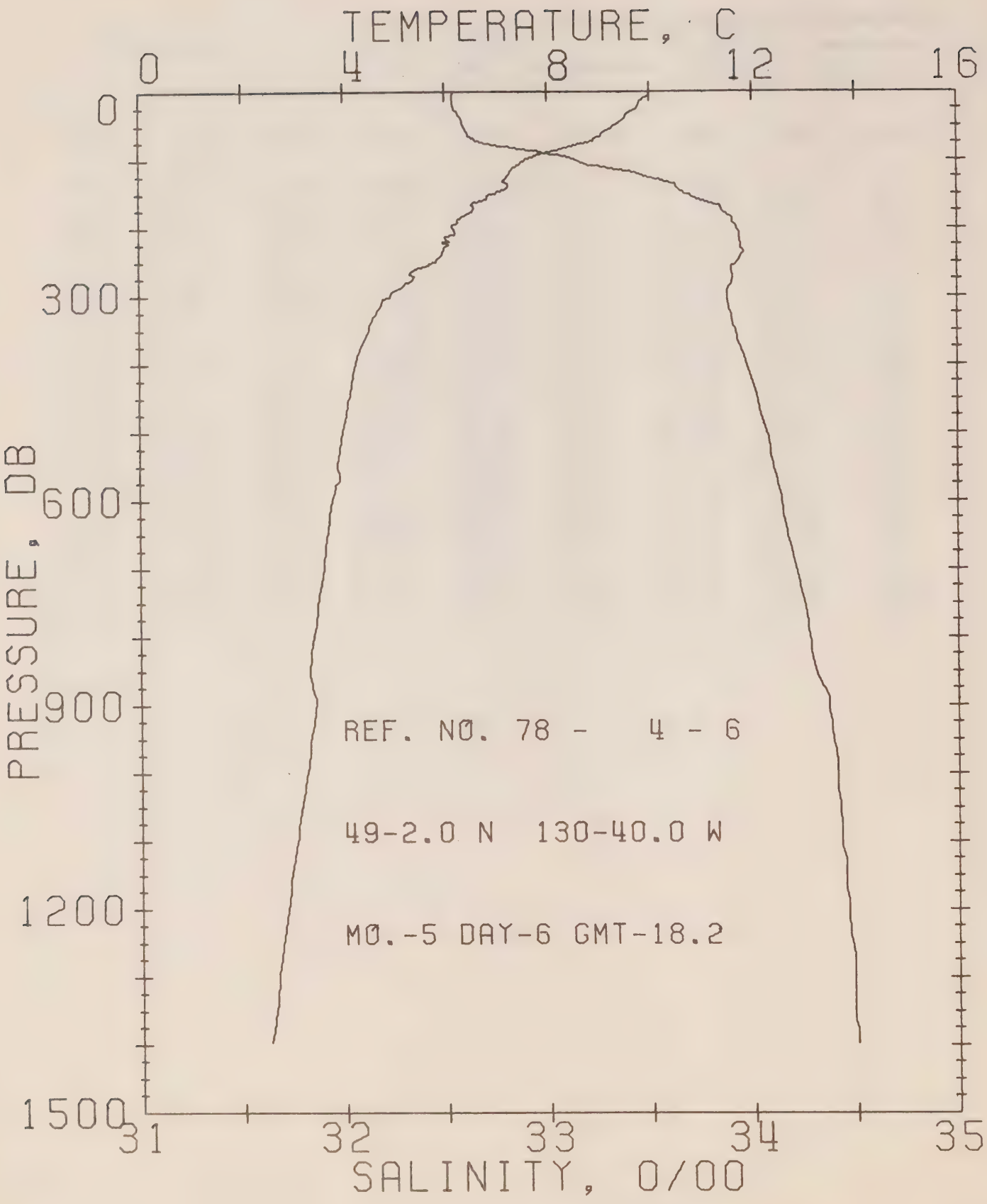
OFFSHORE OCEANOGRAPHY GROUP
REFERENCE NO. 78- 4- 4 DATE 5/ 5/78 STATION 4
POSITION 48-46.0N, 127-40.0W GMT 8.9
RESULTS OF STP CAST 226 POINTS TAKEN FROM ANALOG TRACE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	DELTA D	POT. EN	SOUND
0	10.50	31.73	0	24.34	359.3	0.0	0.0	1488.
10	10.46	31.75	10	24.37	357.5	0.36	0.02	1488.
20	10.29	32.41	20	24.91	306.1	0.70	0.07	1488.
30	10.32	32.50	30	24.97	300.1	1.01	0.15	1489.
50	9.43	32.64	50	25.23	276.1	1.57	0.38	1486.
75	8.76	32.71	75	25.39	261.2	2.25	0.81	1484.
100	8.32	32.81	99	25.53	247.9	2.89	1.38	1483.
125	7.43	33.28	124	26.03	200.6	3.45	2.02	1481.
150	7.03	33.70	149	26.42	164.6	3.90	2.65	1480.
175	7.01	33.86	174	26.54	152.8	4.30	3.31	1480.
200	6.75	33.94	199	26.64	143.5	4.67	4.01	1480.
225	6.68	33.99	223	26.69	139.6	5.02	4.78	1480.
250	6.21	33.95	248	26.72	136.7	5.37	5.62	1479.
300	5.74	33.97	298	26.80	130.0	6.04	7.49	1478.
400	5.07	34.04	397	26.93	117.8	7.27	11.87	1477.
500	4.61	34.10	496	27.03	109.1	8.40	17.05	1476.
600	4.21	34.17	595	27.13	100.3	9.45	22.93	1476.
800	3.74	34.30	793	27.28	86.9	11.30	36.09	1473.
1000	3.36	34.40	991	27.40	76.5	12.91	50.80	1480.
1200	2.86	34.45	1188	27.48	68.7	14.36	67.05	1481.


TEMPERATURE, C
0
4
8
12
16
0
300
600
900
1200
1500
PRESSURE, DB
REF. NO. 78 - 4 - 5
48-51.0 N 128-40.0 W
MO.-5 DAY-6 GMT-12.2
31
32
33
34
35
SALINITY, O/OO

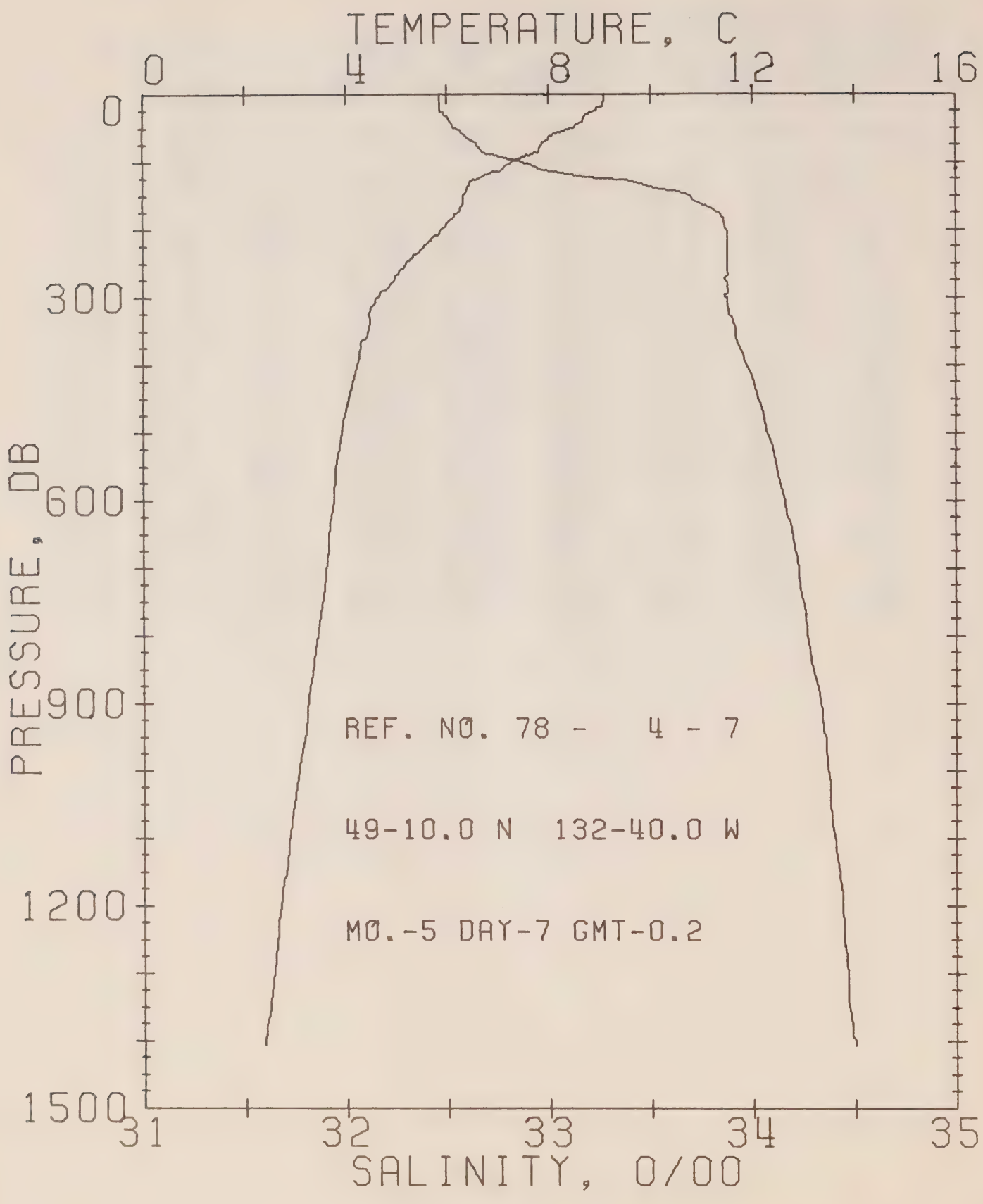
OFFSHORE OCEANOGRAPHY GROUP
REFERENCE NO. 78- 4- 5 DATE 5/ 5/78 STATION 5
POSITION 48-51.0N, 128-40.0W GMT 12.2
RESULTS OF STP CAST 248 POINTS TAKEN FROM ANALOG TRACE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	DELTA D	POT. EN	SOUND
0	10.13	32.08	0	24.68	327.4	0.0	0.0	1487.
10	9.96	32.12	10	24.74	322.1	0.33	0.02	1487.
20	9.95	32.37	20	24.93	303.9	0.64	0.06	1487.
30	9.81	32.37	30	24.96	301.6	0.94	0.14	1487.
50	8.93	32.49	50	25.19	279.4	1.52	0.38	1484.
75	8.37	32.73	75	25.46	254.1	2.18	0.80	1483.
100	7.97	33.17	99	25.87	216.2	2.78	1.33	1482.
125	7.50	33.48	124	26.18	186.6	3.28	1.90	1481.
150	6.96	33.77	149	26.48	158.4	3.71	2.49	1480.
175	6.73	33.87	174	26.59	148.3	4.09	3.13	1479.
200	6.50	33.91	199	26.65	142.7	4.45	3.82	1479.
225	6.13	33.92	223	26.71	137.6	4.80	4.58	1478.
250	5.86	33.93	248	26.75	133.9	5.14	5.40	1477.
300	5.53	33.96	298	26.81	128.1	5.80	7.24	1477.
400	4.89	34.01	397	26.93	117.7	7.03	11.61	1476.
500	4.33	34.06	496	27.03	109.1	8.16	16.79	1475.
600	4.12	34.16	595	27.13	100.0	9.20	22.64	1476.
800	3.70	34.28	793	27.27	87.9	11.05	35.82	1478.
1000	3.27	34.40	991	27.40	75.8	12.67	50.63	1479.
1200	2.88	34.45	1188	27.48	68.7	14.13	66.90	1481.


TEMPERATURE, C
0
4
8
12
16
0
300
600
900
1200
1500
PRESSURE, DB
REF. NO. 78 - 4 - 6
49-2.0 N 130-40.0 W
MO.-5 DAY-6 GMT-18.2
31
32
33
34
35
SALINITY, O/OO

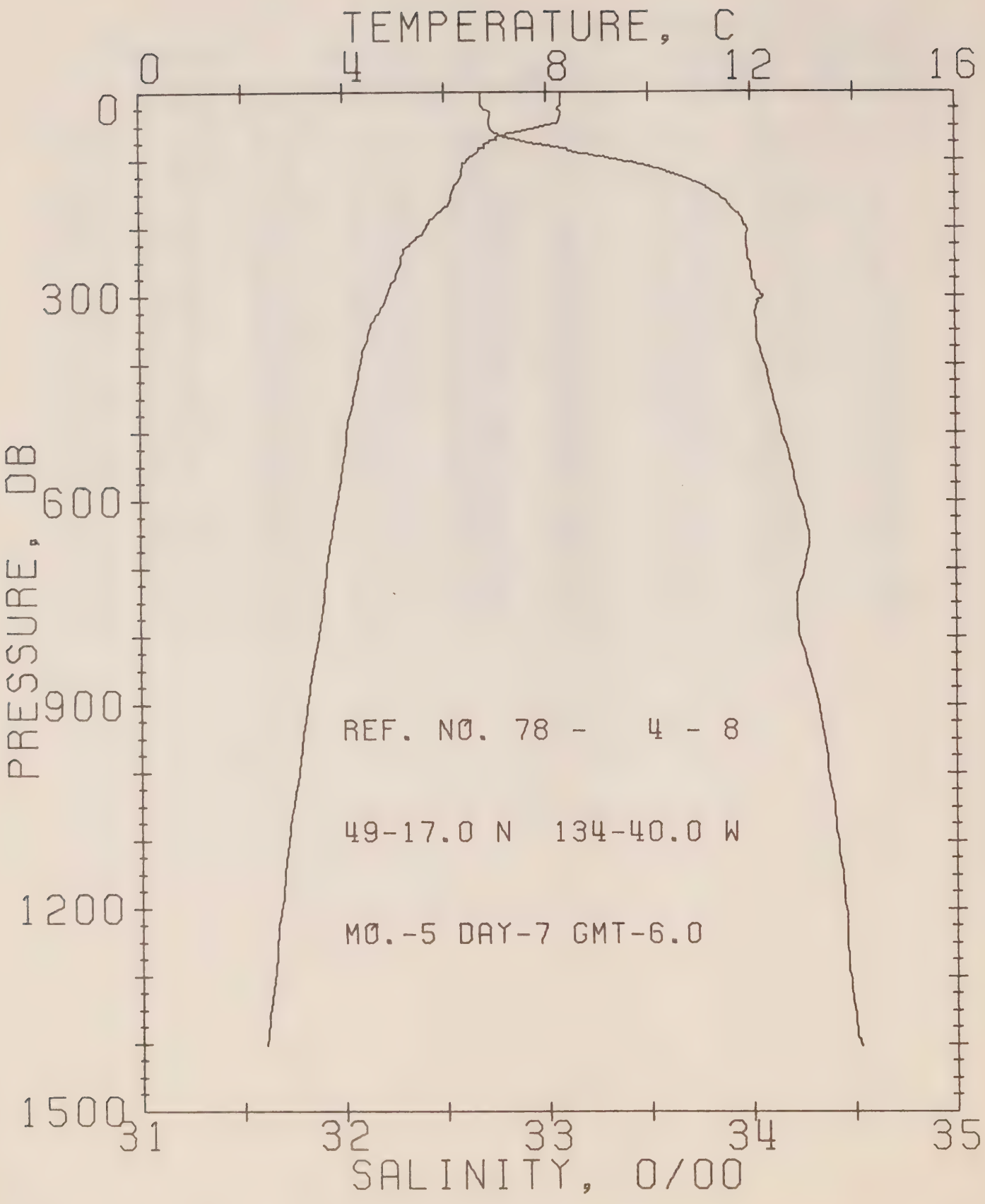
OFFSHORE OCEANOGRAPHY GROUP
REFERENCE NO. 78- 4- 6 DATE 6/ 5/78 STATION 6
POSITION 49- 2.0N, 130-40.0W GMT 18.2
RESULTS OF STP CAST 219 POINTS TAKEN FROM ANALOG TRACE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	DELTA D	POT. EN	SOUND
0	10.00	32.55	0	25.07	290.5	0.0	0.0	1487.
10	9.91	32.54	10	25.07	290.3	0.29	0.01	1487.
20	9.77	32.54	20	25.10	288.1	0.58	0.06	1487.
30	9.60	32.56	30	25.14	284.3	0.87	0.13	1486.
50	9.32	32.59	50	25.21	278.0	1.43	0.36	1486.
75	8.70	32.70	75	25.39	261.1	2.11	0.79	1484.
100	7.57	33.15	99	25.91	212.1	2.70	1.32	1480.
125	7.20	33.50	124	26.23	181.4	3.19	1.88	1480.
150	6.99	33.68	149	26.41	165.6	3.62	2.49	1480.
175	6.54	33.86	174	26.61	146.7	4.01	3.12	1479.
200	6.18	33.93	199	26.71	137.2	4.36	3.80	1478.
225	6.06	33.95	223	26.74	134.5	4.70	4.53	1478.
250	5.81	33.93	248	26.76	133.0	5.03	5.34	1477.
300	4.92	33.88	298	26.82	127.0	5.68	7.15	1474.
400	4.24	33.97	397	26.97	113.3	6.88	11.41	1473.
500	3.98	34.07	496	27.07	104.1	7.97	16.39	1474.
600	3.76	34.14	595	27.15	97.3	8.98	22.05	1475.
800	3.38	34.28	793	27.30	84.7	10.80	34.99	1476.
1000	3.25	34.41	990	27.42	74.7	12.38	49.52	1479.
1200	2.85	34.46	1188	27.49	67.8	13.81	65.47	1481.


TEMPERATURE, C
0
4
8
12
16
0
300
600
900
1200
1500
PRESSURE, DB
REF. NO. 78 - 4 - 7
49-10.0 N 132-40.0 W
MO.-5 DAY-7 GMT-0.2
31
32
33
34
35
SALINITY, O/OO

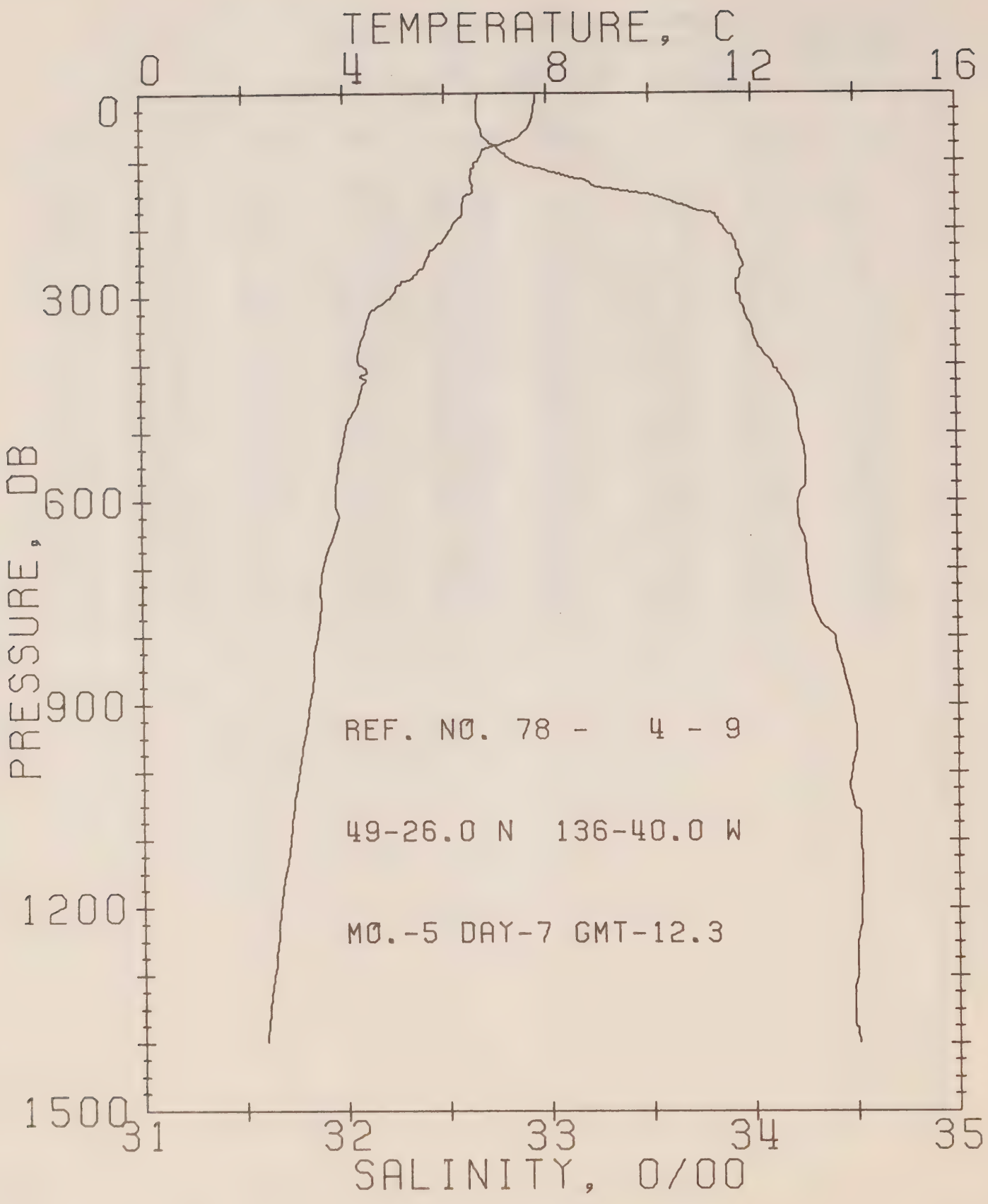
OFFSHORE OCEANOGRAPHY GROUP
REFERENCE NO. 78- 4- 7 DATE 7/ 5/78 STATION 7
POSITION 49-10.0N, 132-40.0W GMT 0.2
RESULTS OF STP CAST 211 POINTS TAKEN FROM ANALOG TRACE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	DELTA D	POT. EN	SOUND
0	9.08	32.47	0	25.15	282.4	0.0	0.0	1484.
10	9.08	32.47	10	25.15	282.7	0.28	0.01	1484.
20	8.97	32.47	20	25.17	281.3	0.57	0.05	1484.
30	8.74	32.49	30	25.22	276.5	0.84	0.13	1483.
50	8.49	32.54	50	25.30	269.5	1.39	0.35	1482.
75	7.85	32.65	75	25.48	252.8	2.04	0.76	1481.
100	7.29	32.87	99	25.73	229.4	2.65	1.31	1479.
125	6.55	33.37	124	26.22	182.6	3.19	1.92	1477.
150	6.33	33.69	149	26.50	156.1	3.61	2.51	1477.
175	6.19	33.83	174	26.63	144.1	3.99	3.13	1477.
200	5.90	33.87	199	26.70	137.9	4.34	3.81	1476.
225	5.55	33.88	223	26.75	133.5	4.68	4.54	1475.
250	5.19	33.88	248	26.79	129.5	5.01	5.34	1474.
300	4.55	33.87	298	26.84	124.7	5.64	7.11	1473.
400	4.23	33.97	397	26.97	113.6	6.83	11.35	1473.
500	3.91	34.07	496	27.08	103.1	7.91	16.28	1473.
600	3.75	34.16	595	27.17	95.8	8.90	21.33	1474.
800	3.44	34.27	793	27.29	85.7	10.71	34.70	1477.
1000	3.06	34.37	990	27.40	75.5	12.31	49.37	1478.
1200	2.69	34.44	1188	27.49	67.5	13.74	65.38	1480.


TEMPERATURE, C
0
4
8
12
16
0
300
600
900
1200
1500
PRESSURE, DB
REF. NO. 78 - 4 - 8
49-17.0 N 134-40.0 W
MO.-5 DAY-7 GMT-6.0
31
32
33
34
35
SALINITY, O/OO

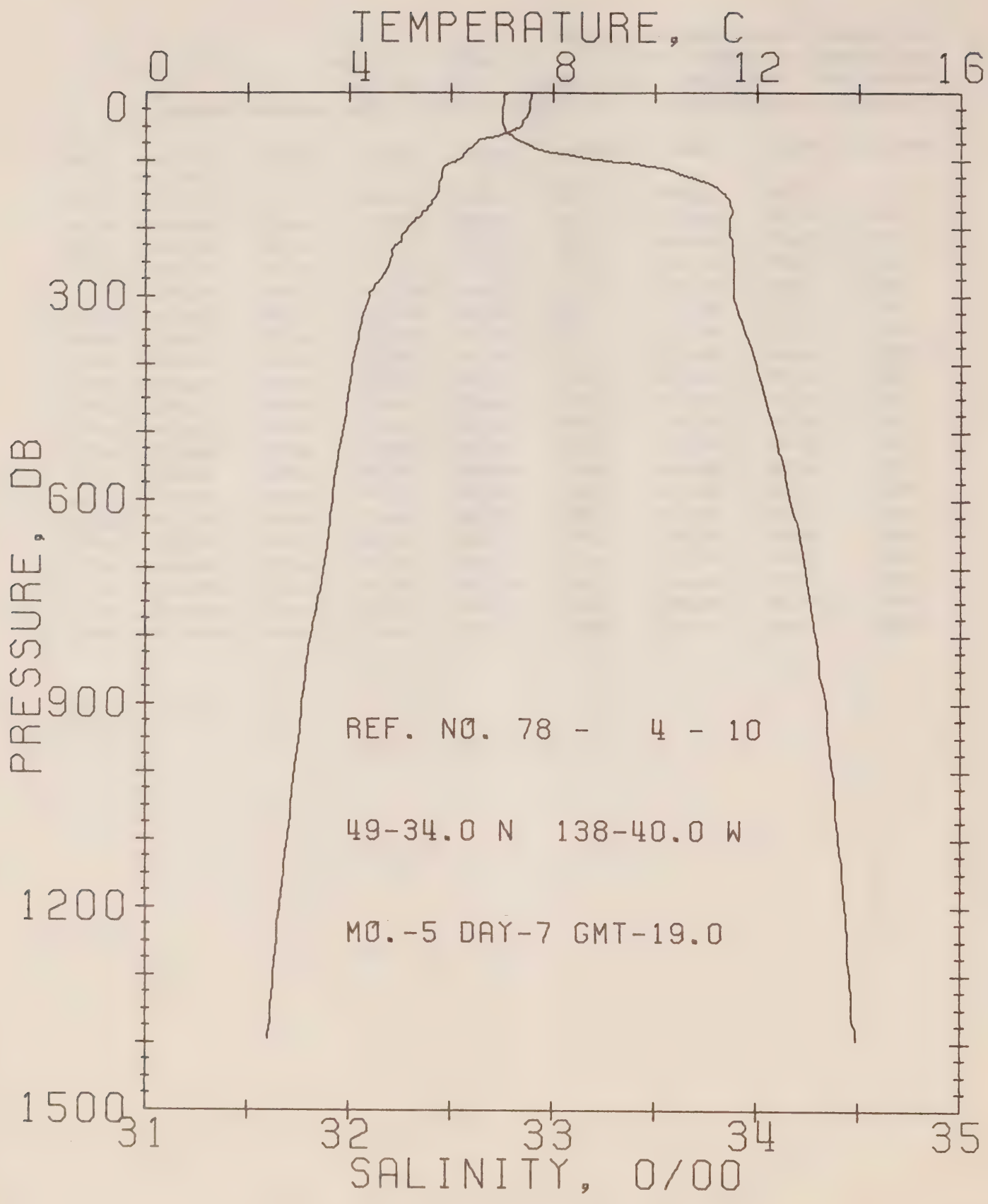
OFFSHORE OCEANOGRAPHY GROUP
REFERENCE NO. 78- 4- 8 DATE 7/ 5/78 STATION 8
POSITION 49-17.0N, 134-40.0W GMT 6.0
RESULTS OF STP CAST 245 POINTS TAKEN FROM ANALOG TRACE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	DELTA D	POT. EN	SOUND
0	8.29	32.69	0	25.44	254.5	0.0	0.0	1481.
10	8.29	32.68	10	25.44	255.6	0.26	0.01	1481.
20	8.28	32.68	20	25.44	255.7	0.51	0.05	1481.
30	8.29	32.73	30	25.47	252.3	0.76	0.12	1482.
50	7.95	32.72	50	25.52	248.5	1.27	0.32	1481.
75	6.85	32.94	75	25.84	217.8	1.86	0.59	1477.
100	6.45	33.36	99	26.23	181.7	2.36	1.14	1476.
125	6.32	33.67	124	26.49	157.4	2.77	1.62	1477.
150	6.12	33.84	149	26.65	142.4	3.15	2.14	1476.
175	5.94	33.93	174	26.74	134.1	3.49	2.71	1476.
200	5.63	33.98	199	26.82	126.6	3.82	3.33	1475.
225	5.31	33.98	223	26.86	123.2	4.13	4.01	1475.
250	5.14	34.00	248	26.89	120.2	4.43	4.74	1474.
300	4.85	34.06	298	26.97	112.7	5.02	6.39	1474.
400	4.32	34.07	397	27.04	107.3	6.14	10.36	1473.
500	4.06	34.15	496	27.13	99.2	7.17	15.08	1474.
600	3.87	34.24	595	27.22	91.3	8.12	20.41	1475.
800	3.49	34.23	793	27.25	89.1	9.90	33.13	1477.
1000	3.08	34.37	990	27.40	75.7	11.53	47.99	1479.
1200	2.74	34.45	1188	27.50	67.0	12.94	63.84	1480.


TEMPERATURE, C
0
4
8
12
16
0
300
600
900
1200
1500
PRESSURE, DB
REF. NO. 78 - 4 - 9
49-26.0 N 136-40.0 W
MO.-5 DAY-7 GMT-12.3
31
32
33
34
35
SALINITY, O/OO

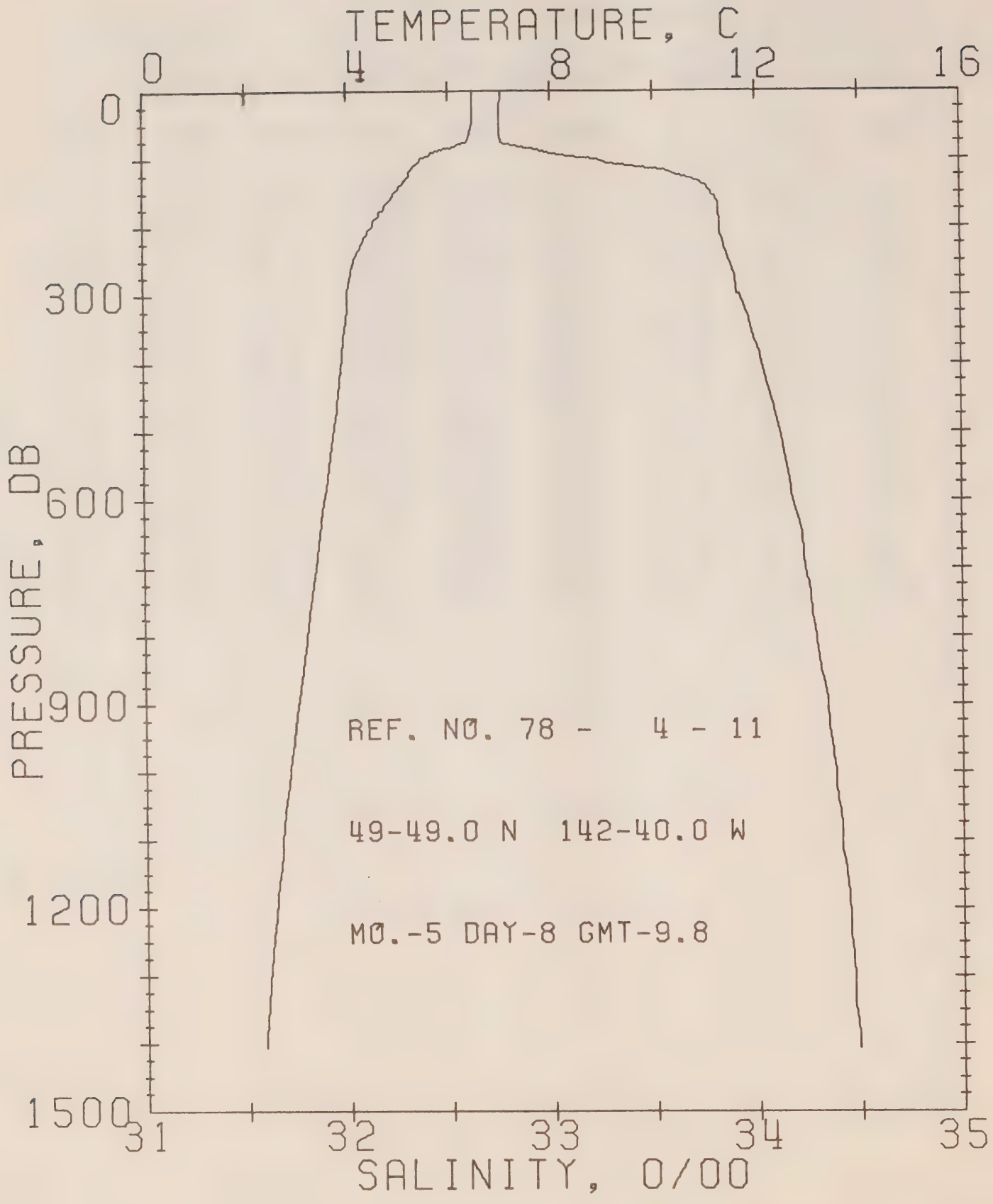
OFFSHORE OCEANOGRAPHY GROUP
REFERENCE NO. 78- 4- 9 DATE 7/ 5/78 STATION 9
POSITION 49-26.0N, 136-40.0W GMT 12.3
RESULTS OF STP CAST 215 POINTS TAKEN FROM ANALOG TRACE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	DELTA D	POT. EN	SOUND
0	7.78	32.67	0	25.50	249.0	0.0	0.0	1479.
10	7.78	32.67	10	25.50	249.5	0.25	0.01	1479.
20	7.77	32.66	20	25.50	250.0	0.50	0.05	1479.
30	7.74	32.66	30	25.50	249.8	0.75	0.11	1479.
50	7.66	32.67	50	25.52	247.9	1.25	0.32	1479.
75	7.13	32.73	75	25.64	236.7	1.86	0.71	1478.
100	6.63	32.85	99	25.80	222.1	2.43	1.21	1476.
125	6.51	33.15	124	26.05	198.5	2.96	1.82	1477.
150	6.44	33.50	149	26.34	171.5	3.43	2.48	1477.
175	6.35	33.77	174	26.57	150.5	3.83	3.14	1478.
200	6.11	33.87	199	26.67	140.7	4.19	3.83	1477.
225	5.83	33.93	223	26.75	133.1	4.53	4.57	1477.
250	5.60	33.96	248	26.80	128.6	4.86	5.36	1476.
300	4.93	33.95	298	26.88	121.9	5.49	7.13	1474.
400	4.34	34.10	397	27.06	104.7	6.62	11.13	1474.
500	4.00	34.23	496	27.20	92.4	7.59	15.60	1474.
600	3.81	34.22	595	27.21	91.7	8.50	20.66	1475.
800	3.43	34.40	793	27.39	76.2	10.23	33.00	1477.
1000	3.06	34.48	990	27.49	67.6	11.63	45.79	1479.
1200	2.68	34.52	1188	27.55	61.5	12.90	60.02	1480.


TEMPERATURE, C
0
4
8
12
16
0
300
600
900
1200
1500
PRESSURE, DB
REF. NØ. 78 - 4 - 10
49-34.0 N 138-40.0 W
MØ.-5 DAY-7 GMT-19.0
31
32
33
34
35
SALINITY, 0/00

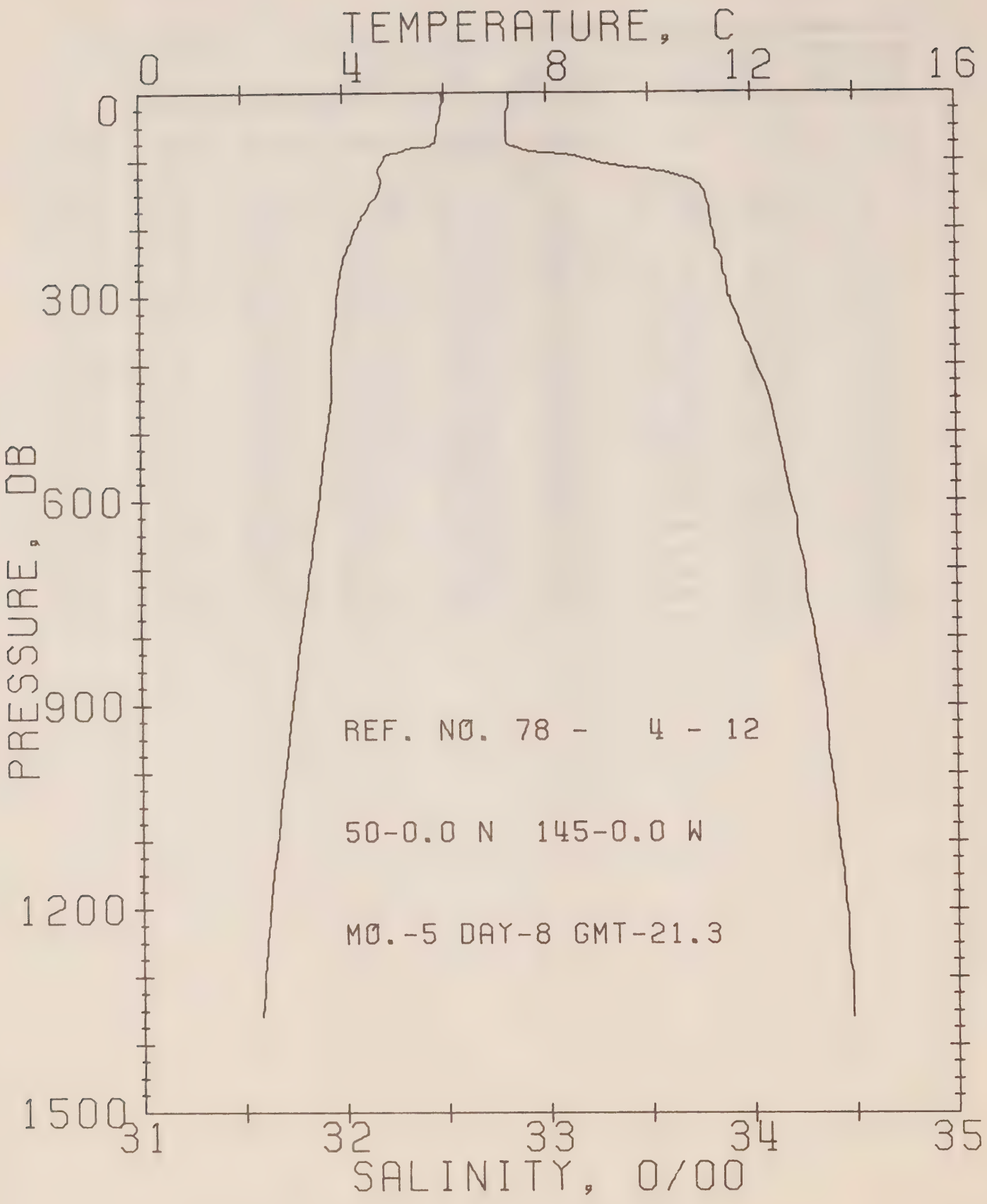
OFFSHORE OCEANOGRAPHY GROUP
REFERENCE NO. 78- 4- 10 DATE 7/ 5/78 STATION 10
POSITION 49-34.0N, 138-40.0W GMT 19.0
RESULTS OF STP CAST 186 POINTS TAKEN FROM ANALOG TRACE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	DELTA D	POT. EN	SOUND
0	7.57	32.79	0	25.63	237.2	0.0	0.0	1478.
10	7.55	32.76	10	25.60	239.6	0.24	0.01	1478.
20	7.55	32.76	20	25.60	239.9	0.48	0.05	1479.
30	7.51	32.75	30	25.60	240.0	0.72	0.11	1479.
50	7.36	32.75	50	25.63	237.9	1.20	0.31	1478.
75	6.47	32.87	75	25.84	218.0	1.77	0.67	1475.
100	6.12	33.26	99	26.19	185.4	2.28	1.13	1475.
125	5.78	33.69	124	26.57	149.5	2.69	1.59	1475.
150	5.72	33.84	149	26.70	137.3	3.05	2.09	1475.
175	5.48	33.88	174	26.76	132.1	3.38	2.64	1474.
200	5.15	33.87	199	26.79	129.3	3.71	3.27	1473.
225	4.89	33.88	223	26.83	125.8	4.03	3.96	1473.
250	4.78	33.89	248	26.84	124.2	4.34	4.72	1473.
300	4.39	33.89	298	26.89	120.3	4.95	6.43	1472.
400	4.05	34.00	397	27.01	109.6	6.10	10.53	1472.
500	3.87	34.09	496	27.10	101.7	7.16	15.38	1473.
600	3.68	34.16	595	27.18	95.0	8.14	20.86	1474.
800	3.25	34.29	793	27.32	82.4	9.91	33.40	1476.
1000	2.92	34.37	990	27.42	73.7	11.46	47.64	1478.
1200	2.53	34.44	1188	27.49	67.2	12.87	63.45	1480.


TEMPERATURE, C
0
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300
600
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1200
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PRESSURE, DB
REF. NO. 78 - 4 - 11
49-49.0 N 142-40.0 W
MO.-5 DAY-8 GMT-9.8
31
32
33
34
35
SALINITY, O/OO

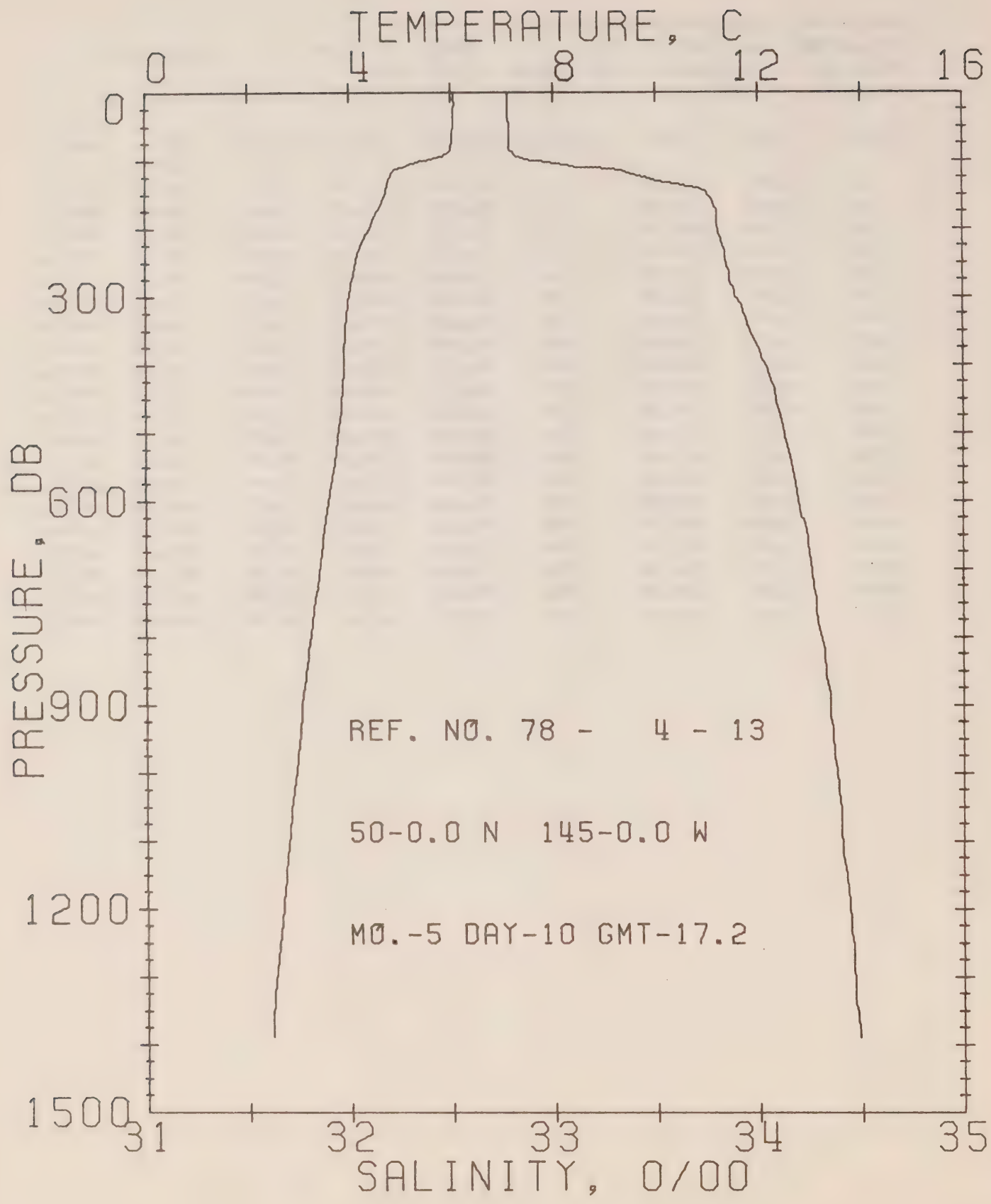
OFFSHORE OCEANOGRAPHY GROUP
REFERENCE NO. 78- 4- 11 DATE 8/ 5/78 STATION 12
POSITION 49-49.0N, 142-40.0W GMT 9.8
RESULTS OF STP CAST 173 POINTS TAKEN FROM ANALOG TRACE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	DELTA D	POT. EN	SOUND
0	6.47	32.76	0	25.75	225.3	0.0	0.0	1474.
10	6.48	32.76	10	25.75	225.7	0.23	0.01	1474.
20	6.49	32.75	20	25.74	226.3	0.45	0.05	1474.
30	6.49	32.75	30	25.74	226.9	0.68	0.10	1475.
50	6.46	32.75	50	25.74	226.8	1.13	0.29	1475.
75	6.35	32.76	75	25.77	225.0	1.70	0.65	1475.
100	5.46	33.21	99	26.23	181.1	2.21	1.11	1472.
125	5.20	33.64	124	26.60	146.4	2.62	1.57	1472.
150	4.95	33.79	149	26.74	132.7	2.96	2.05	1472.
175	4.68	33.82	174	26.80	127.6	3.29	2.59	1471.
200	4.48	33.83	199	26.83	124.8	3.60	3.19	1471.
225	4.29	33.85	223	26.87	121.7	3.91	3.86	1470.
250	4.13	33.87	248	26.90	118.5	4.21	4.59	1470.
300	4.01	33.92	298	26.95	114.1	4.79	6.21	1470.
400	3.88	34.03	397	27.05	105.4	5.89	10.11	1472.
500	3.71	34.11	496	27.14	98.0	6.90	14.76	1473.
600	3.53	34.18	595	27.20	92.3	7.85	20.08	1474.
800	3.18	34.29	793	27.33	81.5	9.58	32.39	1476.
1000	2.82	34.38	990	27.43	72.2	11.12	46.44	1477.
1200	2.54	34.44	1188	27.51	65.5	12.49	61.86	1480.


TEMPERATURE, C
0
4
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16
0
300
600
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1200
1500
PRESSURE, DB
REF. NØ. 78 - 4 - 12
50-0.0 N 145-0.0 W
MØ.-5 DAY-8 GMT-21.3
31
32
33
34
35
SALINITY, 0/00

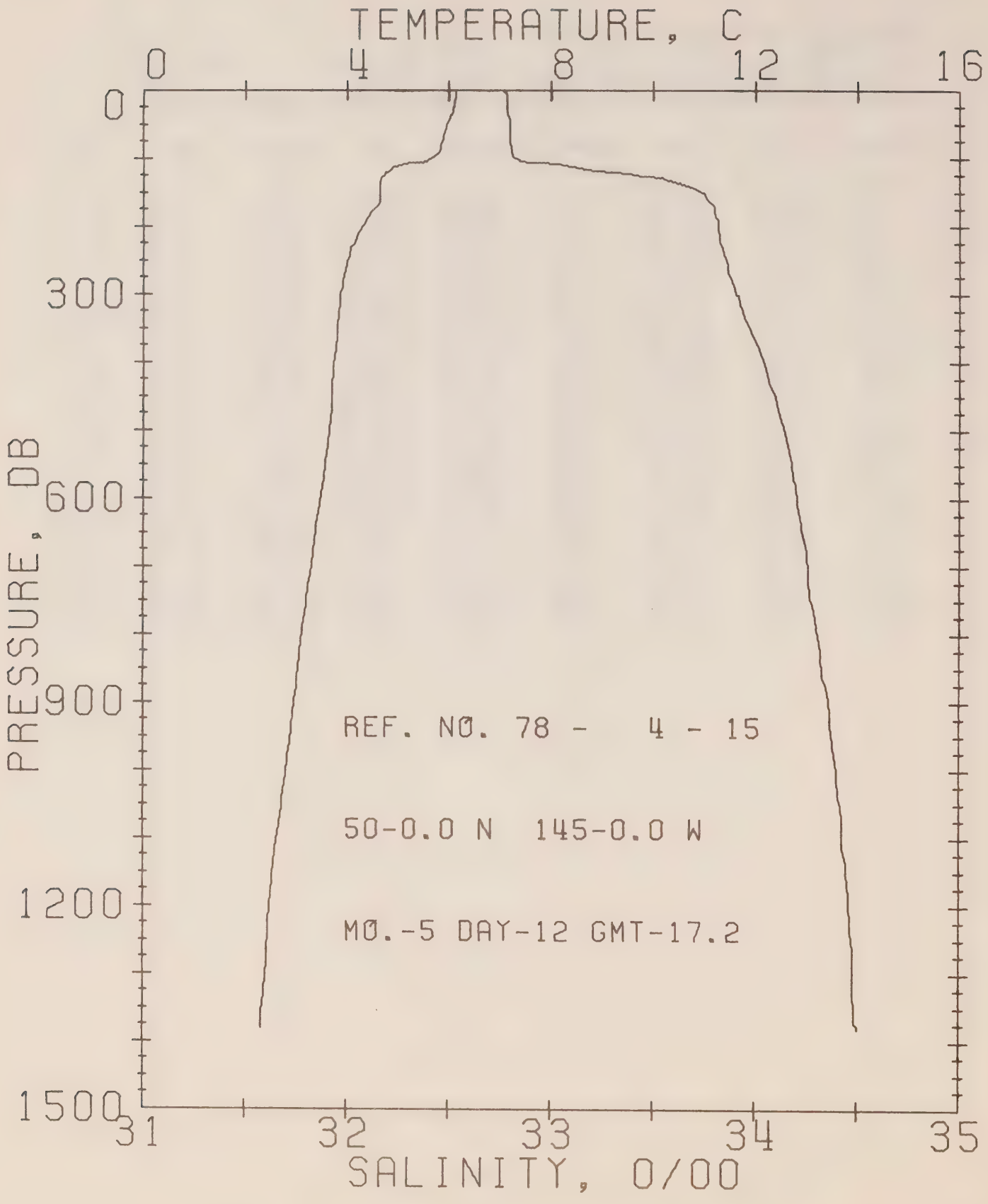
OFFSHORE OCEANOGRAPHY GROUP
REFERENCE NO. 78- 4- 12 DATE 8/ 5/78 STATION P
POSITION 50- 0.0N. 145- 0.0W GMT 21.3
RESULTS OF STP CAST 166 POINTS TAKEN FROM ANALOG TRACE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	DELTA D	POT. EN	SOUND
0	5.96	32.82	0	25.86	214.8	0.0	0.0	1472.
10	5.97	32.82	10	25.86	215.2	0.22	0.01	1472.
20	5.96	32.82	20	25.86	215.2	0.43	0.04	1472.
30	5.95	32.81	30	25.85	216.0	0.65	0.10	1472.
50	5.87	32.81	50	25.86	215.2	1.08	0.27	1472.
75	5.80	32.81	75	25.88	214.5	1.62	0.62	1473.
100	4.79	33.23	99	26.33	171.9	2.10	1.05	1469.
125	4.77	33.69	124	26.69	137.8	2.48	1.49	1470.
150	4.67	33.78	149	26.77	130.2	2.82	1.95	1470.
175	4.43	33.80	174	26.81	126.4	3.14	2.48	1470.
200	4.25	33.81	199	26.84	123.8	3.45	3.08	1470.
225	4.12	33.83	223	26.87	121.3	3.76	3.74	1469.
250	3.99	33.86	248	26.91	118.0	4.05	4.47	1469.
300	3.88	33.89	298	26.94	115.0	4.64	6.09	1470.
400	3.77	34.02	397	27.06	104.8	5.73	10.00	1471.
500	3.66	34.13	496	27.15	96.5	6.73	14.59	1472.
600	3.50	34.19	595	27.22	90.6	7.67	19.83	1473.
800	3.13	34.30	793	27.34	80.1	9.37	31.94	1475.
1000	2.80	34.38	990	27.44	71.6	10.88	45.75	1477.
1200	2.50	34.45	1188	27.52	64.3	12.24	60.93	1479.


TEMPERATURE, C
0
4
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12
16
0
300
600
900
1200
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PRESSURE, DB
REF. NO. 78 - 4 - 13
50-0.0 N 145-0.0 W
MO.-5 DAY-10 GMT-17.2
31
32
33
34
35
SALINITY, O/OO

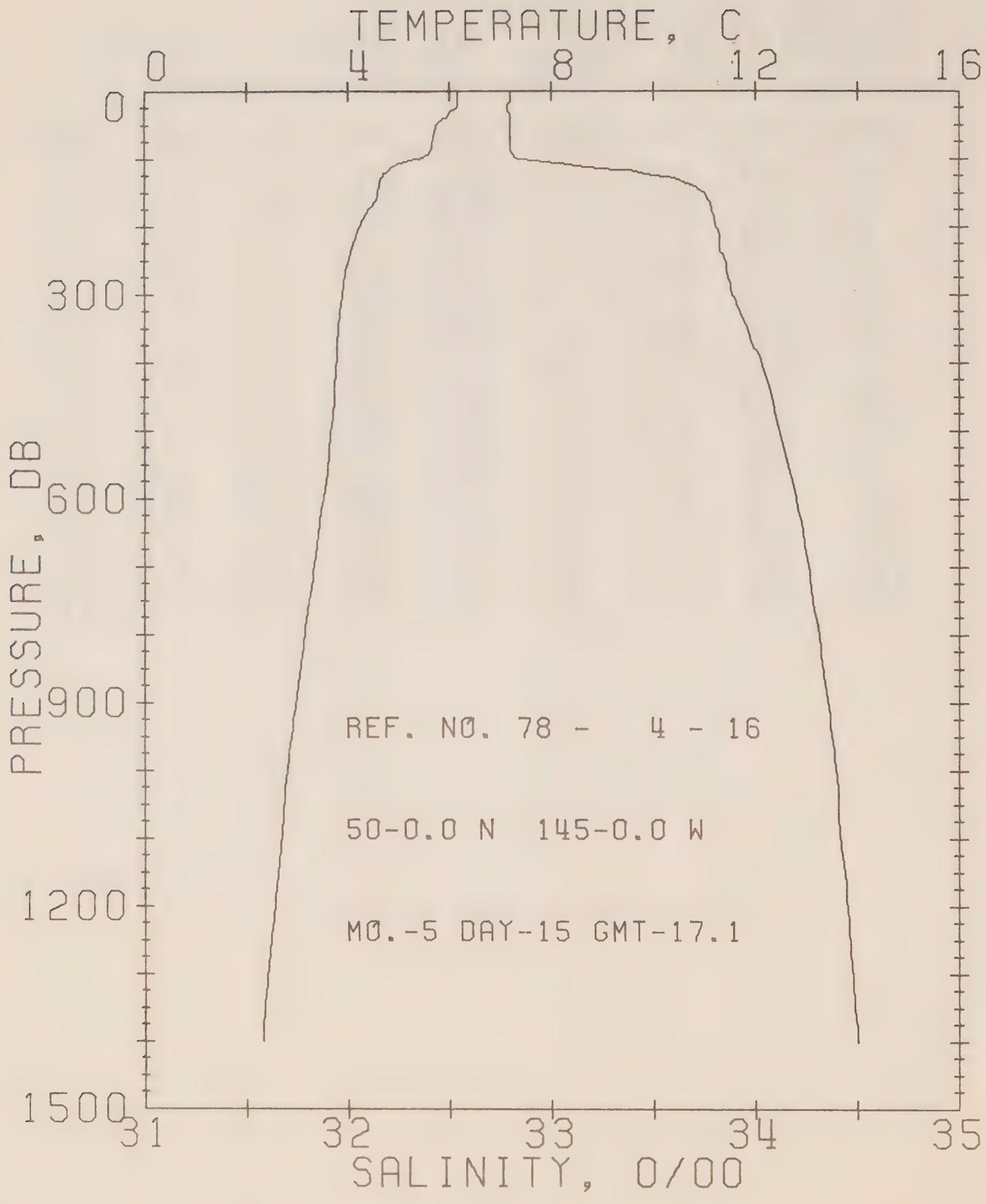
OFFSHORE OCEANOGRAPHY GROUP
REFERENCE NO. 78- 4- 13 DATE 10/ 5/78 STATION P
POSITION 50- 0.0N, 145- 0.0W GMT 17.2
RESULTS OF STP CAST 165 POINTS TAKEN FROM ANALOG TRACE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	DELTA D	POT. EN	SOUND
0	6.06	32.78	0	25.82	219.0	0.0	0.0	1472.
10	6.06	32.78	10	25.82	219.3	0.22	0.01	1473.
20	6.06	32.78	20	25.82	219.4	0.44	0.04	1473.
30	6.06	32.78	30	25.82	219.5	0.66	0.10	1473.
50	6.04	32.79	50	25.83	218.8	1.10	0.28	1473.
75	5.02	32.79	75	25.83	218.8	1.64	0.63	1473.
100	5.48	32.90	99	25.98	204.6	2.18	1.11	1472.
125	4.78	33.47	124	26.51	154.4	2.62	1.61	1470.
150	4.69	33.75	149	26.75	132.3	2.98	2.10	1471.
175	4.53	33.80	174	26.80	127.5	3.30	2.64	1470.
200	4.40	33.81	199	26.82	125.8	3.62	3.25	1470.
225	4.22	33.83	223	26.86	122.4	3.93	3.92	1470.
250	4.12	33.84	248	26.88	120.5	4.23	4.65	1470.
300	4.00	33.89	298	26.93	116.2	4.82	6.31	1470.
400	3.89	34.03	397	27.05	105.2	5.93	10.24	1472.
500	3.78	34.13	496	27.14	97.9	6.94	14.87	1473.
600	3.58	34.20	595	27.21	91.2	7.88	20.16	1474.
800	3.22	34.30	793	27.33	80.8	9.60	32.36	1476.
1000	2.92	34.38	990	27.42	73.2	11.13	46.39	1478.
1200	2.65	34.44	1188	27.50	66.9	12.53	62.10	1480.


TEMPERATURE, C
0
4
8
12
16
0
300
600
900
1200
1500
PRESSURE, DB
REF. NO. 78 - 4 - 15
50-0.0 N 145-0.0 W
MO.-5 DAY-12 GMT-17.2
31
32
33
34
35
SALINITY, O/OO

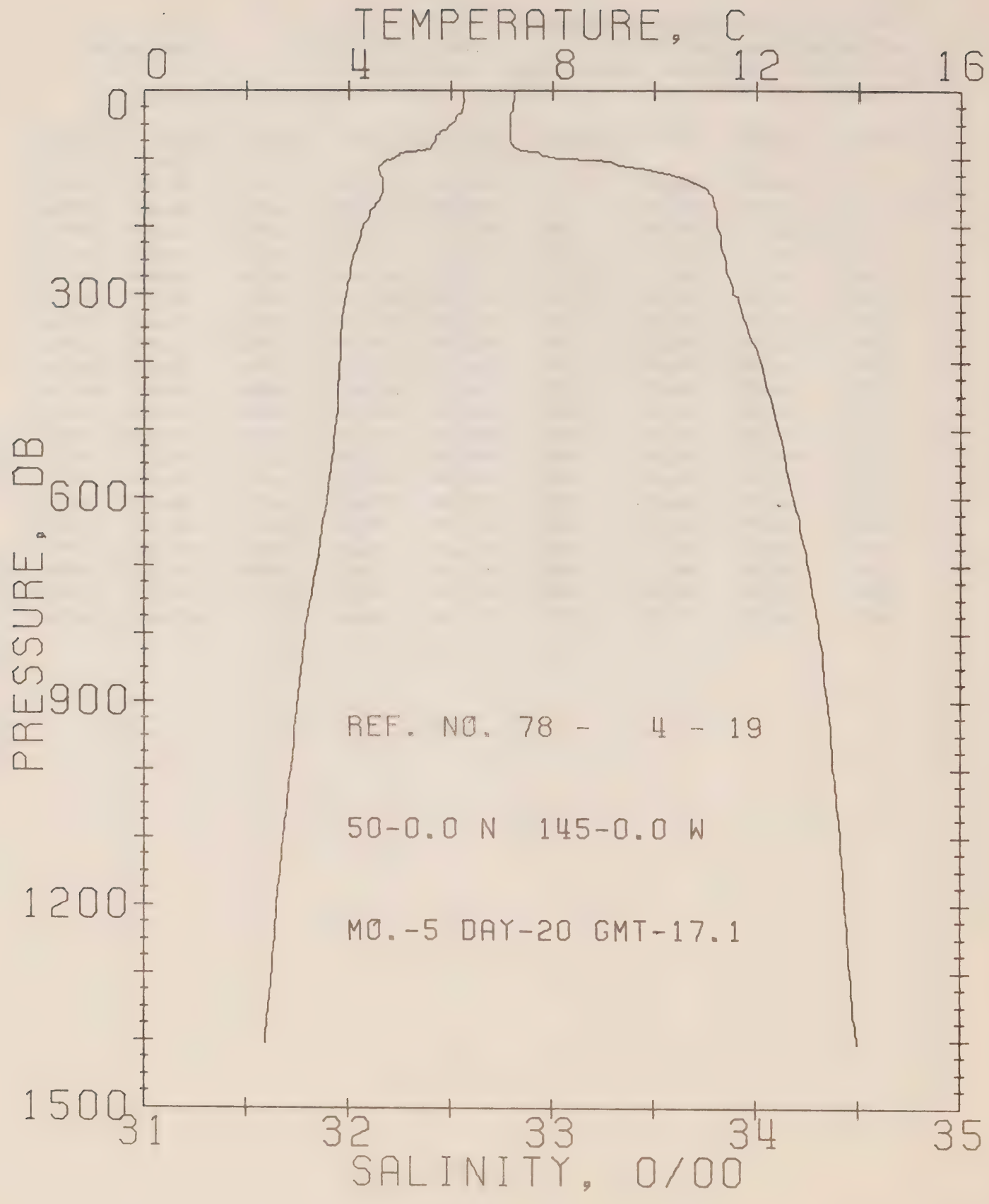
OFFSHORE OCEANOGRAPHY GROUP
REFERENCE NO. 78- 4- 15 DATE 12/ 5/78 STATION P
POSITION 50- 0.0N, 145- 0.0W GMT 17.2
RESULTS OF STP CAST 161 POINTS TAKEN FROM ANALOG TRACE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	DELTA D	POT. EN	SOUND
0	6.13	32.77	0	25.80	220.5	0.0	0.0	1473.
10	6.12	32.79	10	25.82	219.2	0.22	0.01	1473.
20	6.10	32.79	20	25.82	219.1	0.44	0.04	1473.
30	6.07	32.79	30	25.82	218.9	0.66	0.10	1473.
50	5.96	32.80	50	25.85	217.0	1.09	0.28	1473.
75	5.86	32.80	75	25.86	216.2	1.64	0.62	1473.
100	5.68	32.83	99	25.90	212.3	2.17	1.10	1473.
125	4.70	33.45	124	26.51	155.0	2.64	1.63	1470.
150	4.63	33.74	149	26.74	132.9	2.99	2.12	1470.
175	4.52	33.80	174	26.80	127.3	3.31	2.66	1470.
200	4.29	33.82	199	26.84	123.6	3.63	3.26	1470.
225	4.14	33.83	223	26.87	121.5	3.93	3.92	1470.
250	4.02	33.86	248	26.90	118.2	4.23	4.65	1469.
300	3.88	33.91	298	26.96	113.4	4.81	6.27	1470.
400	3.74	34.05	397	27.08	102.6	5.89	10.12	1471.
500	3.65	34.14	496	27.16	95.2	6.88	14.65	1472.
600	3.48	34.21	595	27.23	89.4	7.80	19.81	1473.
800	3.11	34.30	793	27.34	79.6	9.50	31.84	1475.
1000	2.80	34.40	990	27.45	70.7	10.99	45.57	1477.
1200	2.48	34.46	1188	27.53	63.6	12.33	60.53	1479.


TEMPERATURE, C
0
4
8
12
16
0
300
600
900
1200
1500
PRESSURE, DB
REF. NO. 78 - 4 - 16
50-0.0 N 145-0.0 W
MO.-5 DAY-15 GMT-17.1
31
32
33
34
35
SALINITY, O/OO

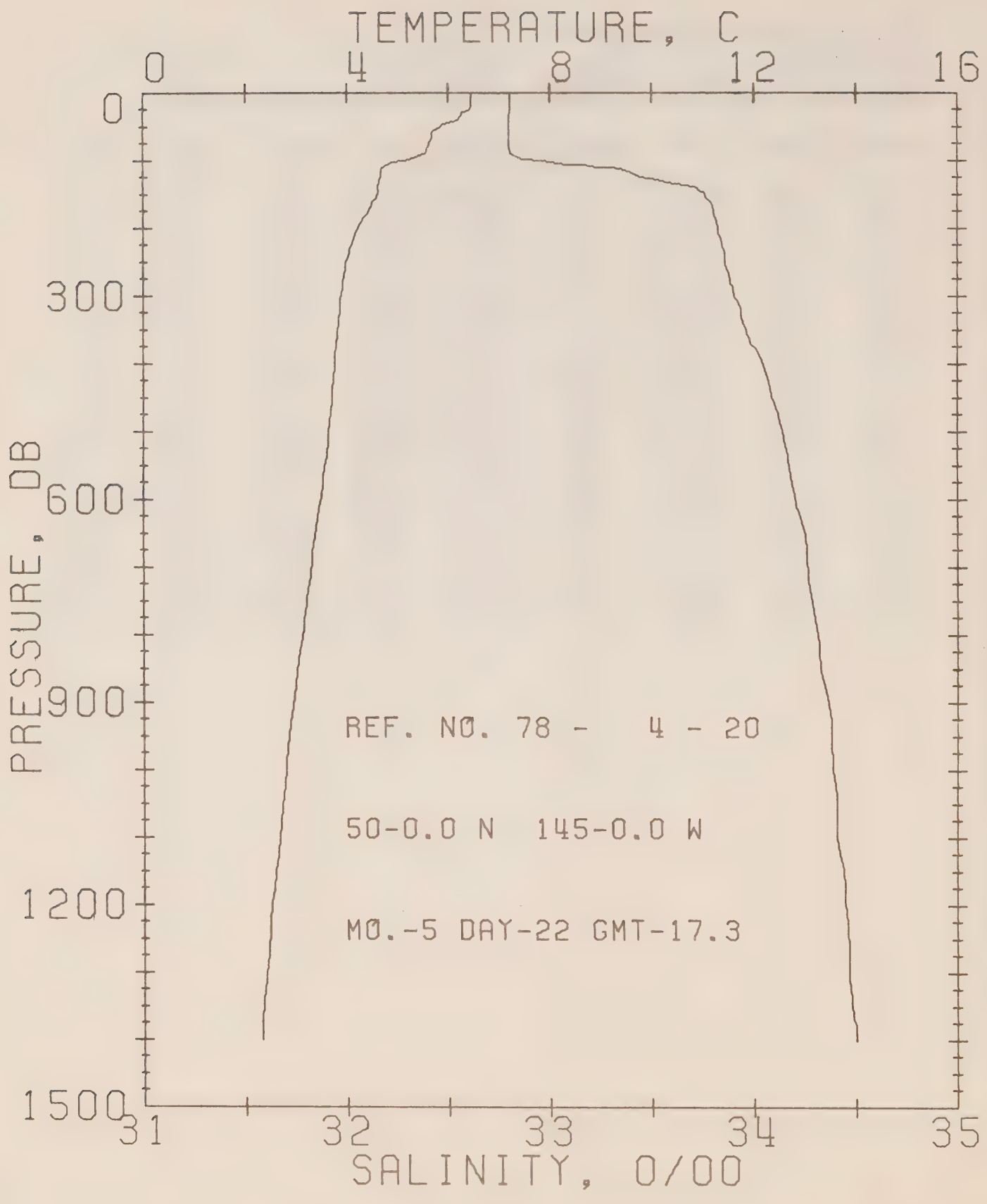
OFFSHORE OCEANOGRAPHY GROUP
REFERENCE NO. 78- 4- 16 DATE 15/ 5/78 STATION P
POSITION 50- 0.0N, 145- 0.0W GMT 17.1
RESULTS OF STP CAST 147 POINTS TAKEN FROM ANALOG TRACE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	DELTA D	POT. EN	SOUND
0	6.16	32.81	0	25.83	217.9	0.0	0.0	1473.
10	6.16	32.80	10	25.82	218.9	0.22	0.01	1473.
20	6.16	32.79	20	25.81	219.8	0.44	0.04	1473.
30	6.02	32.79	30	25.83	218.3	0.66	0.10	1473.
50	5.74	32.80	50	25.87	214.6	1.09	0.28	1472.
75	5.66	32.80	75	25.88	213.8	1.63	0.62	1472.
100	5.37	32.85	99	25.96	207.1	2.15	1.09	1471.
125	4.68	33.53	124	26.58	148.4	2.60	1.59	1470.
150	4.58	33.75	149	26.75	131.8	2.94	2.07	1470.
175	4.41	33.79	174	26.81	126.9	3.26	2.61	1470.
200	4.22	33.81	199	26.84	123.6	3.58	3.21	1469.
225	4.11	33.83	223	26.87	121.2	3.88	3.87	1469.
250	4.01	33.86	248	26.90	118.4	4.18	4.59	1469.
300	3.90	33.89	298	26.94	115.2	4.77	6.23	1470.
400	3.77	34.03	397	27.06	104.1	5.86	10.12	1471.
500	3.67	34.12	496	27.14	97.2	6.87	14.73	1472.
600	3.52	34.20	595	27.22	90.3	7.80	19.98	1474.
800	3.14	34.31	793	27.35	79.3	9.50	32.02	1475.
1000	2.80	34.40	990	27.45	70.7	11.00	45.75	1477.
1200	2.55	34.45	1188	27.51	65.0	12.35	60.96	1480.


TEMPERATURE, C
0
4
8
12
16
0
300
600
900
1200
1500
PRESSURE, DB
REF. NO. 78 - 4 - 19
50-0.0 N 145-0.0 W
MO.-5 DAY-20 GMT-17.1
31
32
33
34
35
SALINITY, O/OO

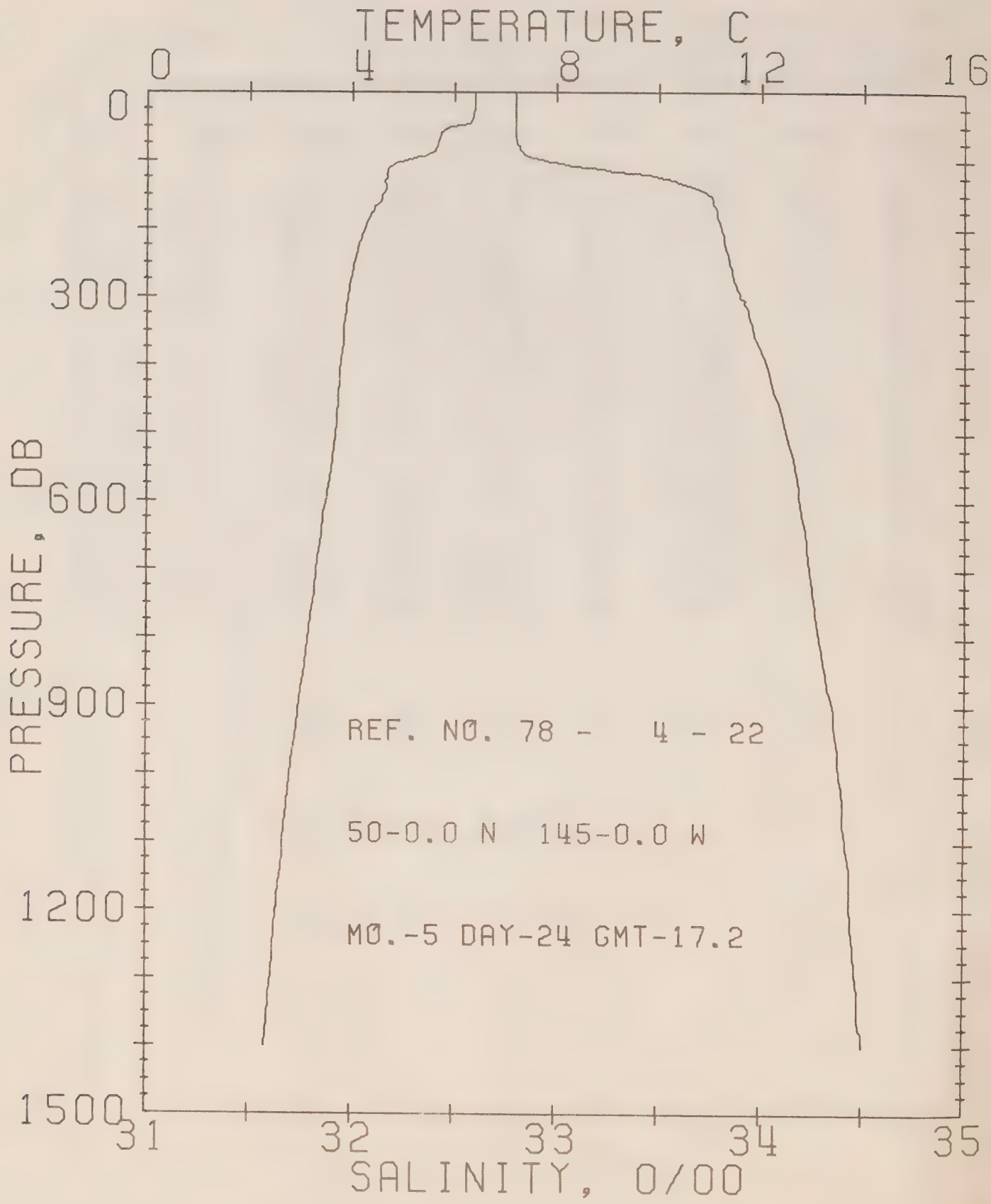
OFFSHORE OCEANOGRAPHY GROUP
REFERENCE NO. 78- 4- 19 DATE 20/ 5/78 STATION P
POSITION 50- 0.0N, 145- 0.0W GMT 17.1
RESULTS OF STP CAST 169 POINTS TAKEN FROM ANALOG TRACE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	DELTA D	POT. EN	SOUND
0	6.22	32.81	0	25.82	218.6	0.0	0.0	1473.
10	6.22	32.81	10	25.82	218.9	0.22	0.01	1473.
20	6.22	32.80	20	25.81	219.8	0.44	0.04	1473.
30	6.19	32.80	30	25.82	219.5	0.66	0.10	1473.
50	5.96	32.79	50	25.84	217.8	1.10	0.28	1473.
75	5.65	32.79	75	25.88	214.5	1.64	0.62	1472.
100	4.85	33.03	99	26.16	187.9	2.15	1.08	1469.
125	4.61	33.59	124	26.63	143.5	2.55	1.54	1470.
150	4.63	33.76	149	26.76	131.3	2.89	2.01	1470.
175	4.42	33.80	174	26.81	126.4	3.21	2.55	1470.
200	4.25	33.80	199	26.83	124.7	3.53	3.15	1470.
225	4.14	33.82	223	26.86	122.3	3.83	3.81	1470.
250	4.04	33.85	248	26.89	119.5	4.14	4.55	1470.
300	3.93	33.88	298	26.93	116.3	4.73	6.20	1470.
400	3.79	34.02	397	27.05	105.4	5.83	10.12	1471.
500	3.71	34.10	496	27.13	98.9	6.85	14.80	1473.
600	3.55	34.17	595	27.20	92.6	7.81	20.16	1474.
800	3.11	34.30	793	27.34	80.0	9.52	32.35	1475.
1000	2.85	34.37	990	27.42	73.2	11.04	46.29	1477.
1200	2.57	34.43	1188	27.49	66.9	12.44	61.90	1480.


TEMPERATURE, C
0
4
8
12
16
0
300
600
900
1200
1500
PRESSURE, DB
REF. NØ. 78 - 4 - 20
50-0.0 N 145-0.0 W
MØ.-5 DAY-22 GMT-17.3
31
32
33
34
35
SALINITY, 0/00

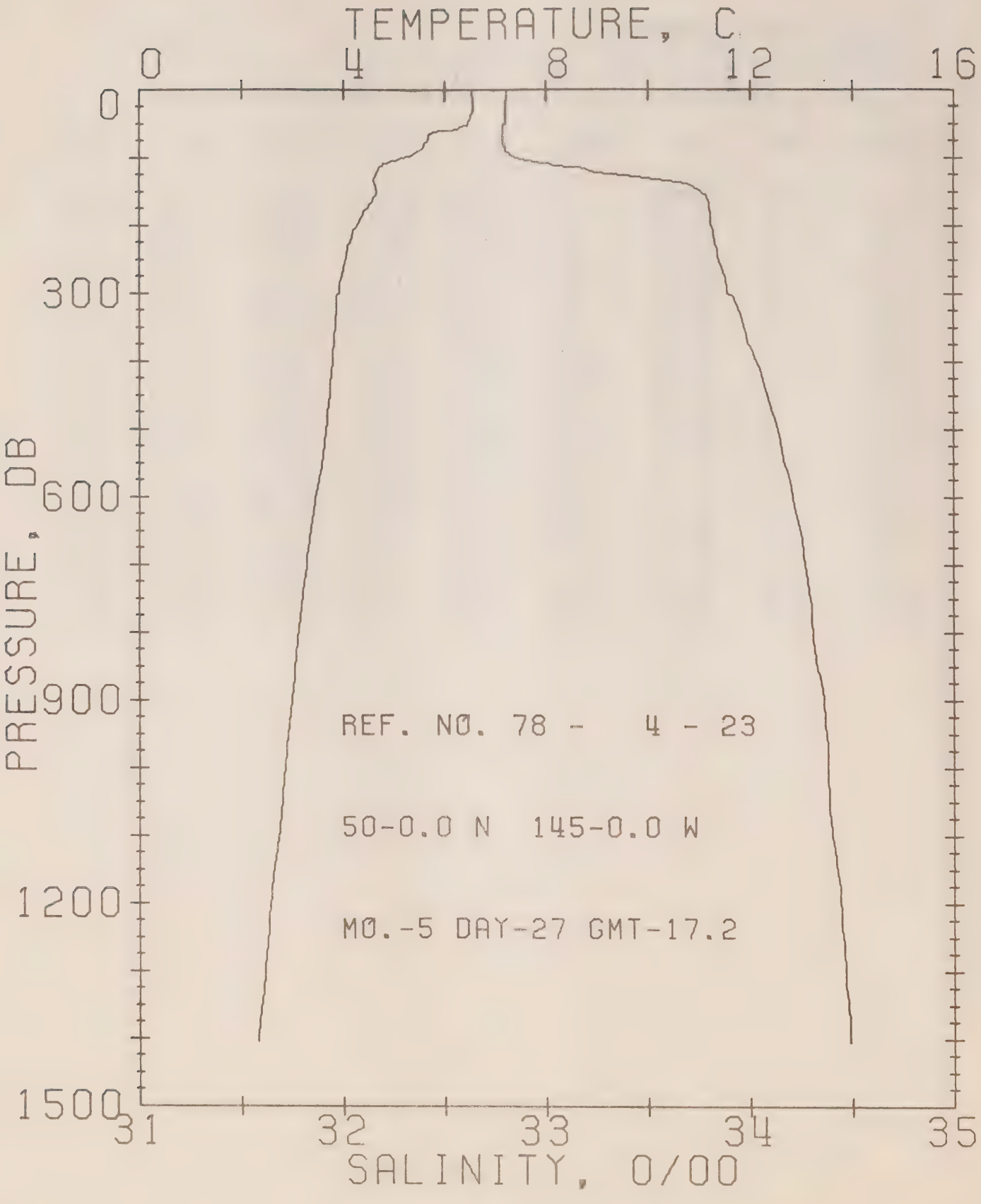
OFFSHORE OCEANOGRAPHY GROUP
REFERENCE NO. 78- 4- 20 DATE 22/ 5/78 STATION P
POSITION 50- 0.0N, 145- 0.0W GMT 17.3
RESULTS OF STP CAST 178 POINTS TAKEN FROM ANALOG TRACE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	DELTA D	POT. EN	SOUND
0	6.46	32.81	0	25.79	221.5	0.0	0.0	1474.
10	6.46	32.81	10	25.79	221.8	0.22	0.01	1474.
20	6.46	32.81	20	25.79	222.0	0.44	0.05	1474.
30	6.26	32.81	30	25.82	219.6	0.66	0.10	1474.
50	5.85	32.80	50	25.86	215.8	1.10	0.28	1472.
75	5.63	32.80	75	25.89	213.5	1.64	0.62	1472.
100	5.16	32.94	99	26.05	198.0	2.16	1.09	1471.
125	4.65	33.47	124	26.53	153.0	2.59	1.57	1470.
150	4.61	33.76	149	26.76	131.0	2.94	2.06	1470.
175	4.39	33.81	174	26.82	125.2	3.26	2.59	1470.
200	4.21	33.83	199	26.86	122.0	3.56	3.18	1469.
225	4.07	33.85	223	26.89	119.3	3.87	3.83	1469.
250	3.98	33.86	248	26.91	117.9	4.16	4.55	1469.
300	3.89	33.91	298	26.96	113.5	4.74	6.17	1470.
400	3.75	34.05	397	27.08	102.7	5.83	10.04	1471.
500	3.64	34.14	496	27.17	95.1	6.82	14.57	1472.
600	3.48	34.20	595	27.23	89.7	7.74	19.74	1473.
800	3.12	34.31	793	27.35	79.1	9.42	31.68	1475.
1000	2.80	34.39	990	27.44	71.1	10.91	45.32	1477.
1200	2.52	34.45	1188	27.51	64.7	12.27	60.55	1479.


TEMPERATURE, C
0
4
8
12
16
0
300
600
900
1200
1500
PRESSURE, DB
REF. NØ. 78 - 4 - 22
50-0.0 N 145-0.0 W
MØ.-5 DAY-24 GMT-17.2
31
32
33
34
35
SALINITY, 0/00

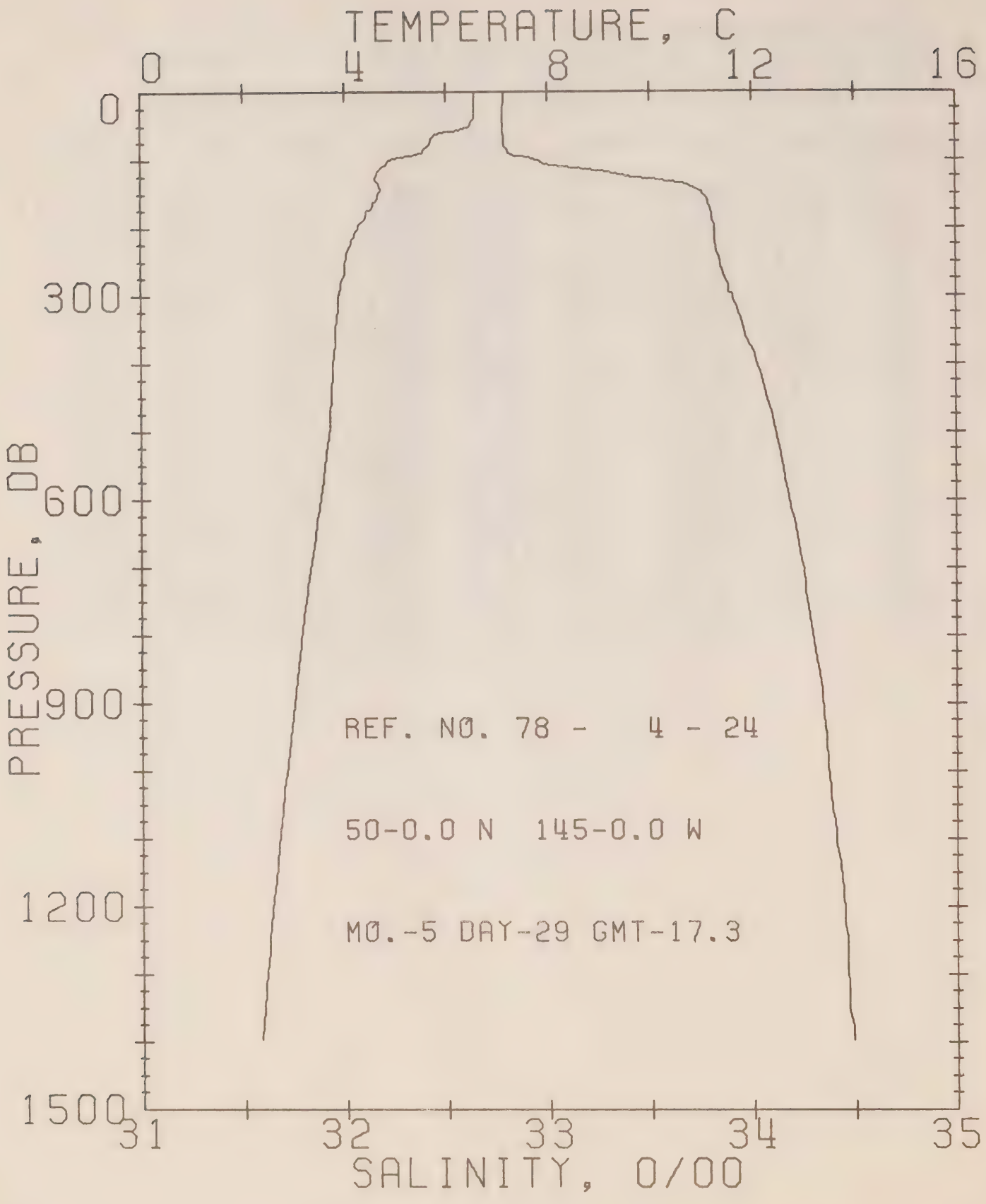
OFFSHORE OCEANOGRAPHY GROUP
REFERENCE NO. 78- 4- 22 DATE 24/ 5/78 STATION P
POSITION 50- 0.0N, 145- 0.0W GMT 17.2
RESULTS OF STP CAST 162 POINTS TAKEN FROM ANALOG TRACE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	DELTA D	POT. EN	SOUND
0	6.39	32.80	0	25.79	221.3	0.0	0.0	1474.
10	6.39	32.80	10	25.79	221.7	0.22	0.01	1474.
20	6.39	32.80	20	25.79	221.8	0.44	0.05	1474.
30	6.38	32.80	30	25.79	221.8	0.67	0.10	1474.
50	6.05	32.80	50	25.83	218.1	1.11	0.28	1473.
75	5.67	32.81	75	25.89	213.2	1.64	0.62	1472.
100	5.06	32.94	99	26.06	196.7	2.17	1.09	1470.
125	4.67	33.52	124	26.56	149.7	2.60	1.58	1470.
150	4.61	33.74	149	26.75	132.2	2.95	2.07	1470.
175	4.39	33.79	174	26.81	126.7	3.27	2.60	1470.
200	4.24	33.81	199	26.84	123.9	3.58	3.20	1470.
225	4.12	33.83	223	26.87	121.6	3.89	3.87	1469.
250	4.04	33.85	248	26.89	119.2	4.19	4.60	1470.
300	3.92	33.90	298	26.94	114.6	4.78	6.24	1470.
400	3.79	34.03	397	27.06	104.6	5.87	10.12	1471.
500	3.68	34.13	496	27.15	96.8	6.87	14.73	1472.
600	3.50	34.19	595	27.22	90.7	7.81	19.96	1473.
800	3.16	34.29	793	27.33	81.4	9.53	32.20	1475.
1000	2.82	34.39	990	27.44	71.6	11.05	46.09	1477.
1200	2.55	34.44	1188	27.51	65.6	12.41	61.35	1480.


TEMPERATURE, C
0
4
8
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16
PRESSURE, DB
0
300
600
900
1200
1500
REF. NØ. 78 - 4 - 23
50-0.0 N 145-0.0 W
MØ.-5 DAY-27 GMT-17.2
31
32
33
34
35
SALINITY, 0/00

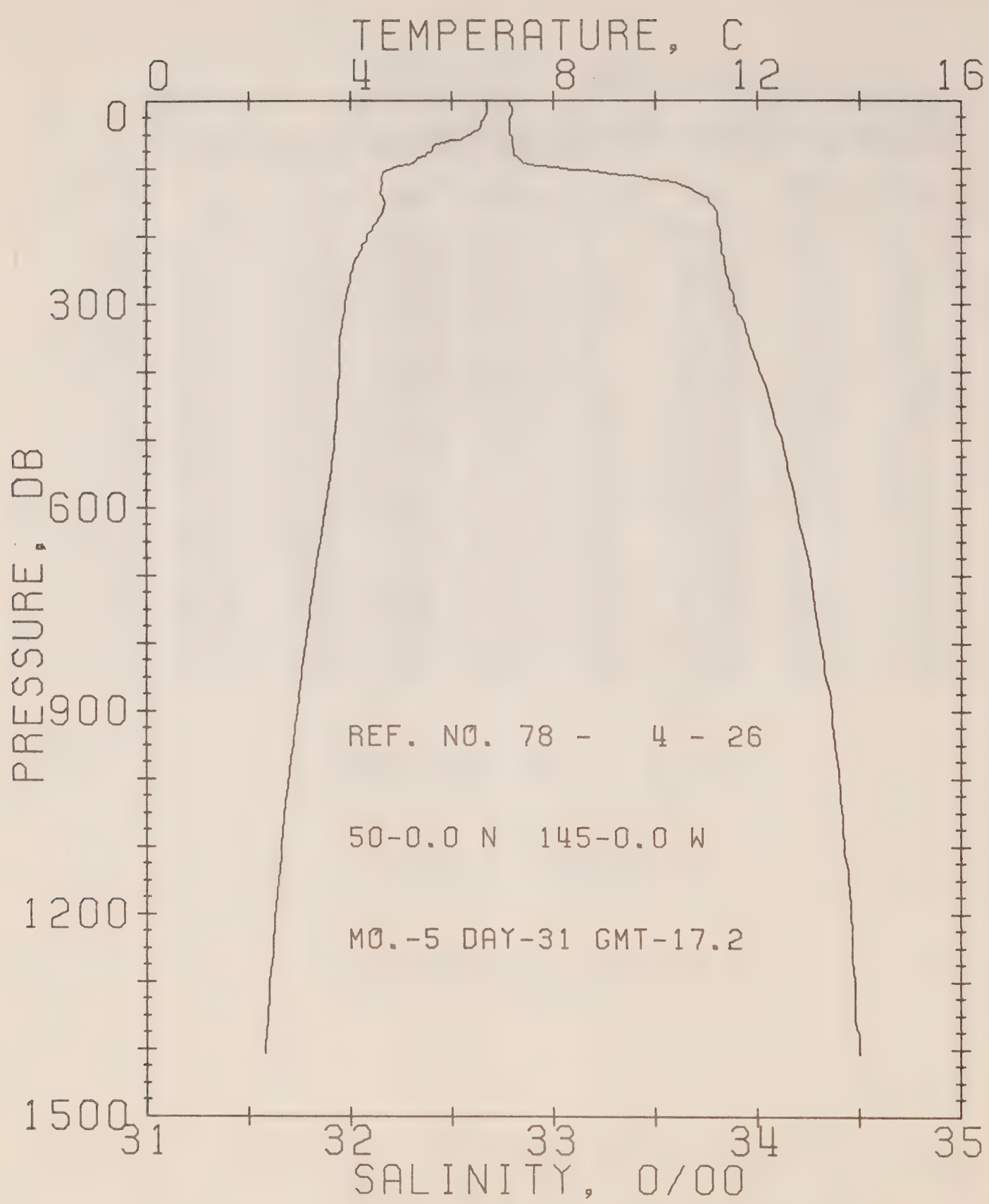
OFFSHORE OCEANOGRAPHY GROUP
REFERENCE NO. 78- 4- 23 DATE 27/ 5/78 STATION P
POSITION 50- 0.0N. 145- 0.0W GMT 17.2
RESULTS OF STP CAST 165 POINTS TAKEN FROM ANALOG TRACE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	DELTA D	POT. EN	SOUND
0	6.53	32.81	0	25.78	222.3	0.0	0.0	1474.
10	6.54	32.81	10	25.78	222.8	0.22	0.01	1475.
20	6.55	32.80	20	25.77	223.8	0.45	0.05	1475.
30	6.55	32.80	30	25.77	223.8	0.67	0.10	1475.
50	6.44	32.80	50	25.78	223.2	1.12	0.28	1475.
75	5.63	32.79	75	25.88	214.3	1.66	0.63	1472.
100	5.16	32.85	99	25.98	204.7	2.19	1.10	1470.
125	4.62	33.35	124	26.44	161.6	2.65	1.63	1469.
150	4.65	33.75	149	26.75	131.9	3.01	2.12	1470.
175	4.44	33.80	174	26.81	126.5	3.33	2.66	1470.
200	4.26	33.81	199	26.84	124.1	3.64	3.25	1470.
225	4.11	33.83	223	26.87	121.3	3.94	3.92	1469.
250	4.03	33.85	248	26.89	119.4	4.25	4.64	1470.
300	3.92	33.89	298	26.94	115.4	4.83	6.28	1470.
400	3.79	34.03	397	27.06	104.4	5.92	10.16	1471.
500	3.65	34.13	496	27.16	96.0	6.92	14.74	1472.
600	3.45	34.21	595	27.24	89.0	7.85	19.93	1473.
800	3.11	34.31	793	27.35	79.4	9.52	31.82	1475.
1000	2.85	34.38	990	27.43	72.6	11.03	45.63	1478.
1200	2.56	34.44	1188	27.50	65.8	12.42	61.21	1480.


TEMPERATURE, C
0
4
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12
16
0
300
600
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1200
1500
PRESSURE, DB
REF. NO. 78 - 4 - 24
50-0.0 N 145-0.0 W
MO.-5 DAY-29 GMT-17.3
31
32
33
34
35
SALINITY, O/OO

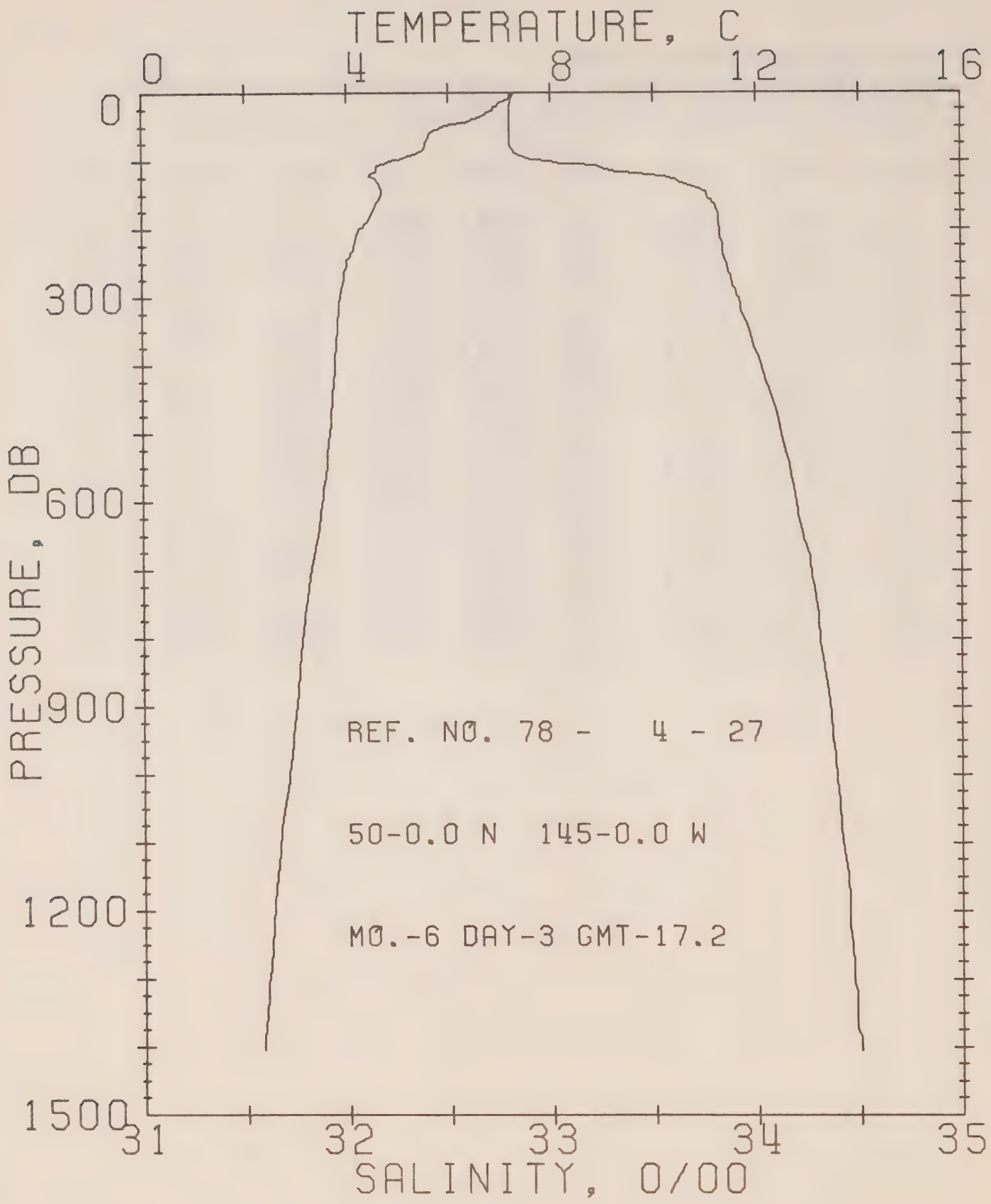
OFFSHORE OCEANOGRAPHY GROUP
REFERENCE NO. 78- 4- 24 DATE 29/ 5/78 STATION P
POSITION 50- 0.0N, 145- 0.0W GMT 17.3
RESULTS OF STP CAST 168 POINTS TAKEN FROM ANALOG TRACE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	DELTA D	POT. EN	SOUND
0	6.57	32.79	0	25.76	224.3	0.0	0.0	1474.
10	6.57	32.79	10	25.76	224.7	0.22	0.01	1475.
20	6.56	32.78	20	25.76	225.1	0.45	0.05	1475.
30	6.56	32.78	30	25.75	225.6	0.67	0.10	1475.
50	6.45	32.78	50	25.77	224.4	1.13	0.29	1475.
75	5.67	32.79	75	25.87	214.7	1.67	0.63	1472.
100	4.93	32.94	99	26.08	195.5	2.20	1.10	1470.
125	4.60	33.42	124	26.49	156.2	2.64	1.61	1469.
150	4.67	33.76	149	26.76	131.5	2.99	2.10	1470.
175	4.46	33.80	174	26.81	126.7	3.31	2.63	1470.
200	4.26	33.82	199	26.85	123.3	3.62	3.23	1470.
225	4.10	33.82	223	26.87	121.5	3.93	3.89	1469.
250	4.00	33.85	248	26.90	119.0	4.23	4.62	1469.
300	3.88	33.91	298	26.96	113.4	4.81	6.25	1470.
400	3.77	34.03	397	27.06	104.5	5.91	10.14	1471.
500	3.68	34.12	496	27.14	97.6	6.91	14.76	1472.
600	3.52	34.18	595	27.21	91.6	7.86	20.06	1474.
800	3.14	34.29	793	27.33	80.7	9.58	32.25	1475.
1000	2.83	34.37	990	27.42	72.9	11.10	46.23	1477.
1200	2.54	34.45	1188	27.51	65.4	12.48	61.70	1480.


TEMPERATURE, C
0
4
8
12
16
0
300
600
900
1200
1500
PRESSURE, DB
REF. NO. 78 - 4 - 26
50-0.0 N 145-0.0 W
MO.-5 DAY-31 GMT-17.2
31
32
33
34
35
SALINITY, O/OO

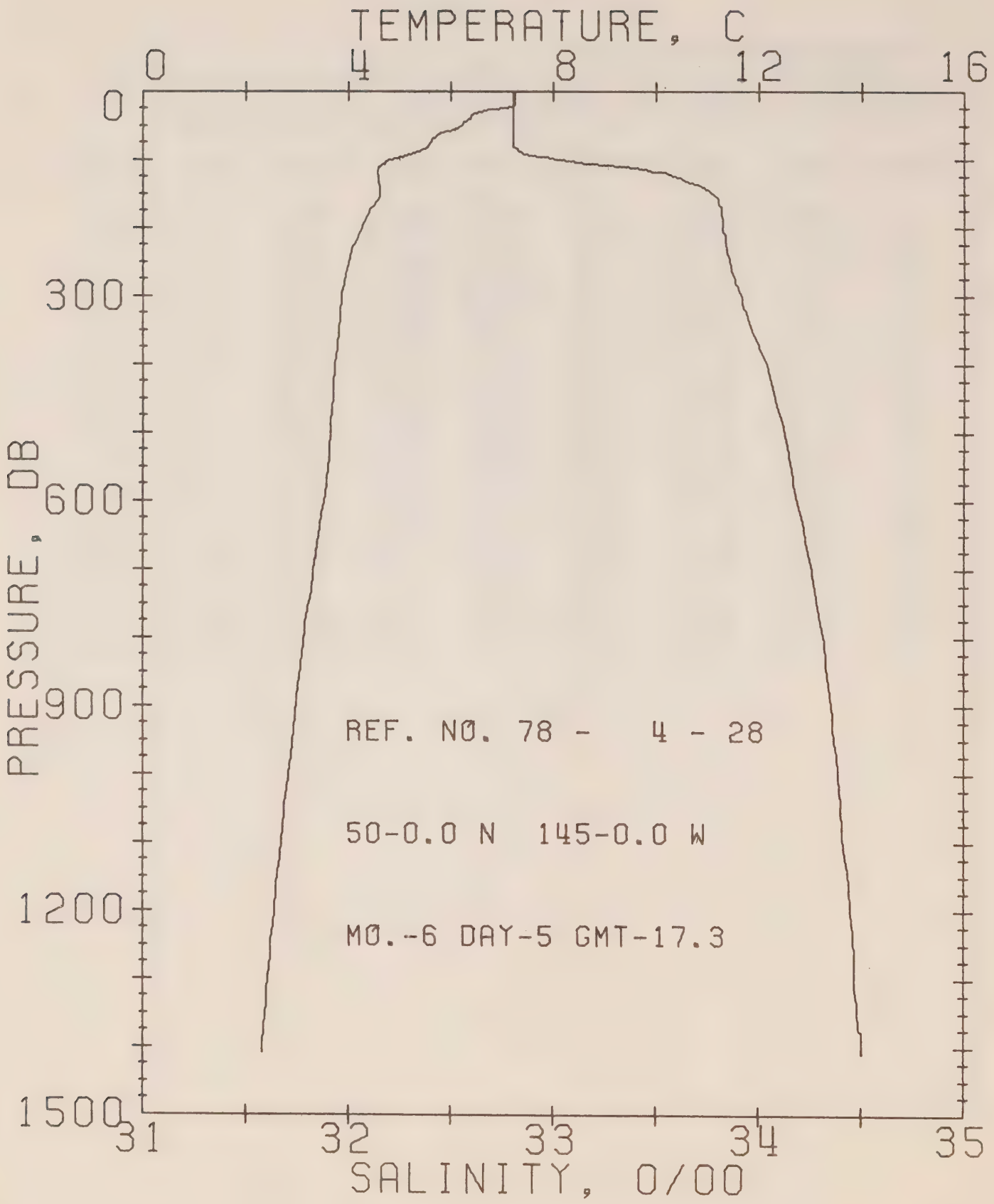
OFFSHORE OCEANOGRAPHY GROUP
REFERENCE NO. 78- 4- 26 DATE 31/ 5/78 STATION P
POSITION 50- 0.0N, 145- 0.0W GMT 17.2
RESULTS OF STP CAST 175 POINTS TAKEN FROM ANALOG TRACE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	DELTA D	POT. EN	SOUND
0	6.70	32.79	0	25.74	225.9	0.0	0.0	1475.
10	6.70	32.80	10	25.75	225.6	0.23	0.01	1475.
20	6.67	32.80	20	25.76	225.2	0.45	0.05	1475.
30	6.61	32.79	30	25.76	225.5	0.68	0.10	1475.
50	6.38	32.79	50	25.79	222.8	1.13	0.29	1474.
75	5.56	32.81	75	25.90	211.9	1.67	0.63	1472.
100	4.84	33.04	99	26.17	187.0	2.18	1.09	1469.
125	4.62	33.64	124	26.66	139.9	2.58	1.54	1470.
150	4.68	33.77	149	26.76	131.0	2.91	2.01	1470.
175	4.54	33.81	174	26.81	126.8	3.23	2.54	1470.
200	4.34	33.82	199	26.84	124.1	3.55	3.14	1470.
225	4.18	33.83	223	26.86	121.9	3.86	3.81	1470.
250	4.03	33.85	248	26.89	119.1	4.16	4.54	1470.
300	3.90	33.89	298	26.94	115.2	4.74	6.18	1470.
400	3.78	34.01	397	27.05	105.3	5.84	10.08	1471.
500	3.68	34.12	496	27.14	97.2	6.85	14.72	1472.
600	3.51	34.19	595	27.22	91.0	7.79	19.99	1473.
800	3.12	34.31	793	27.35	79.2	9.49	32.03	1475.
1000	2.79	34.40	990	27.45	70.2	10.97	45.64	1477.
1200	2.52	34.46	1188	27.52	64.2	12.31	60.64	1480.


TEMPERATURE, C
0
4
8
12
16
0
300
600
900
1200
1500
PRESSURE, DB
REF. NO. 78 - 4 - 27
50-0.0 N 145-0.0 W
MO.-6 DAY-3 GMT-17.2
31
32
33
34
35
SALINITY, O/OO

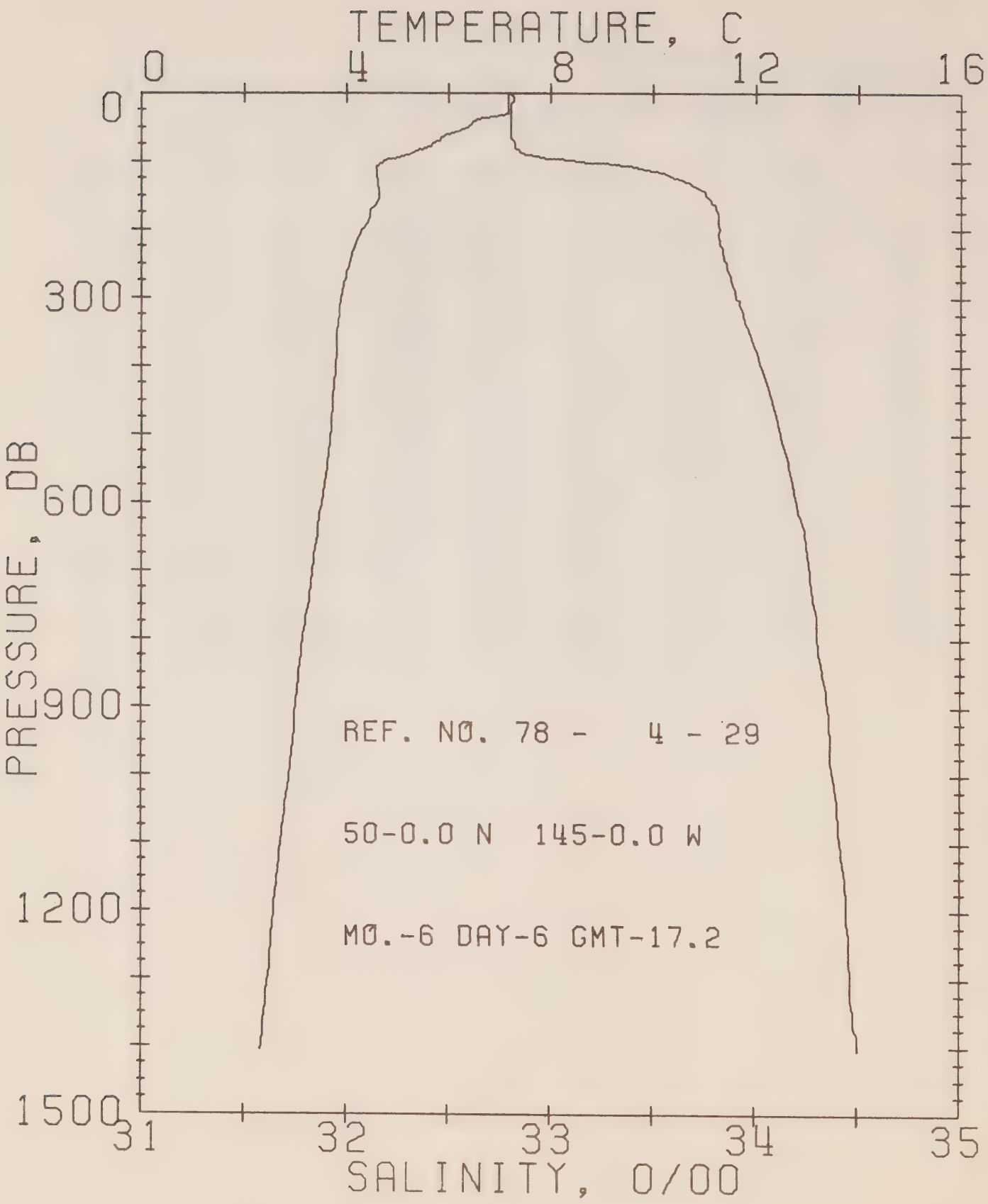
OFFSHORE OCEANOGRAPHY GROUP
REFFRENCE NO. 78- 4- 27 DATE 3/ 6/78 STATION P
POSITION 50- 0.0N, 145- 0.0W GMT 17.2
RESULTS OF STP CAST 186 POINTS TAKEN FROM ANALOG TRACE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	DELTA D	POT. EN	SOUND
0	7.29	32.81	0	25.68	231.9	0.0	0.0	1477.
10	7.18	32.81	10	25.69	231.2	0.23	0.01	1477.
20	6.92	32.80	20	25.72	228.4	0.46	0.05	1476.
30	6.75	32.80	30	25.75	226.4	0.69	0.10	1476.
50	5.92	32.80	50	25.85	216.7	1.13	0.29	1473.
75	5.54	32.80	75	25.90	212.4	1.67	0.63	1472.
100	4.91	32.96	99	26.09	193.7	2.19	1.09	1470.
125	4.55	33.58	124	26.63	143.3	2.60	1.56	1469.
150	4.68	33.76	149	26.76	131.6	2.94	2.04	1470.
175	4.49	33.82	174	26.82	125.5	3.27	2.57	1470.
200	4.26	33.83	199	26.85	122.7	3.58	3.17	1470.
225	4.13	33.84	223	26.88	120.6	3.88	3.83	1470.
250	4.00	33.86	248	26.90	118.1	4.18	4.55	1469.
300	3.87	33.92	298	26.97	112.6	4.76	6.17	1470.
400	3.75	34.03	397	27.06	104.2	5.85	10.05	1471.
500	3.65	34.12	496	27.15	96.9	6.85	14.64	1472.
600	3.49	34.19	595	27.22	90.6	7.79	19.88	1473.
800	3.10	34.31	793	27.35	79.1	9.47	31.85	1475.
1000	2.83	34.39	990	27.44	71.6	10.97	45.61	1477.
1200	2.53	34.45	1188	27.51	64.9	12.34	60.87	1480.


TEMPERATURE, C
0
4
8
12
16
0
300
600
900
1200
1500
PRESSURE, DB
REF. NØ. 78 - 4 - 28
50-0.0 N 145-0.0 W
MØ.-6 DAY-5 GMT-17.3
31
32
33
34
35
SALINITY, 0/00

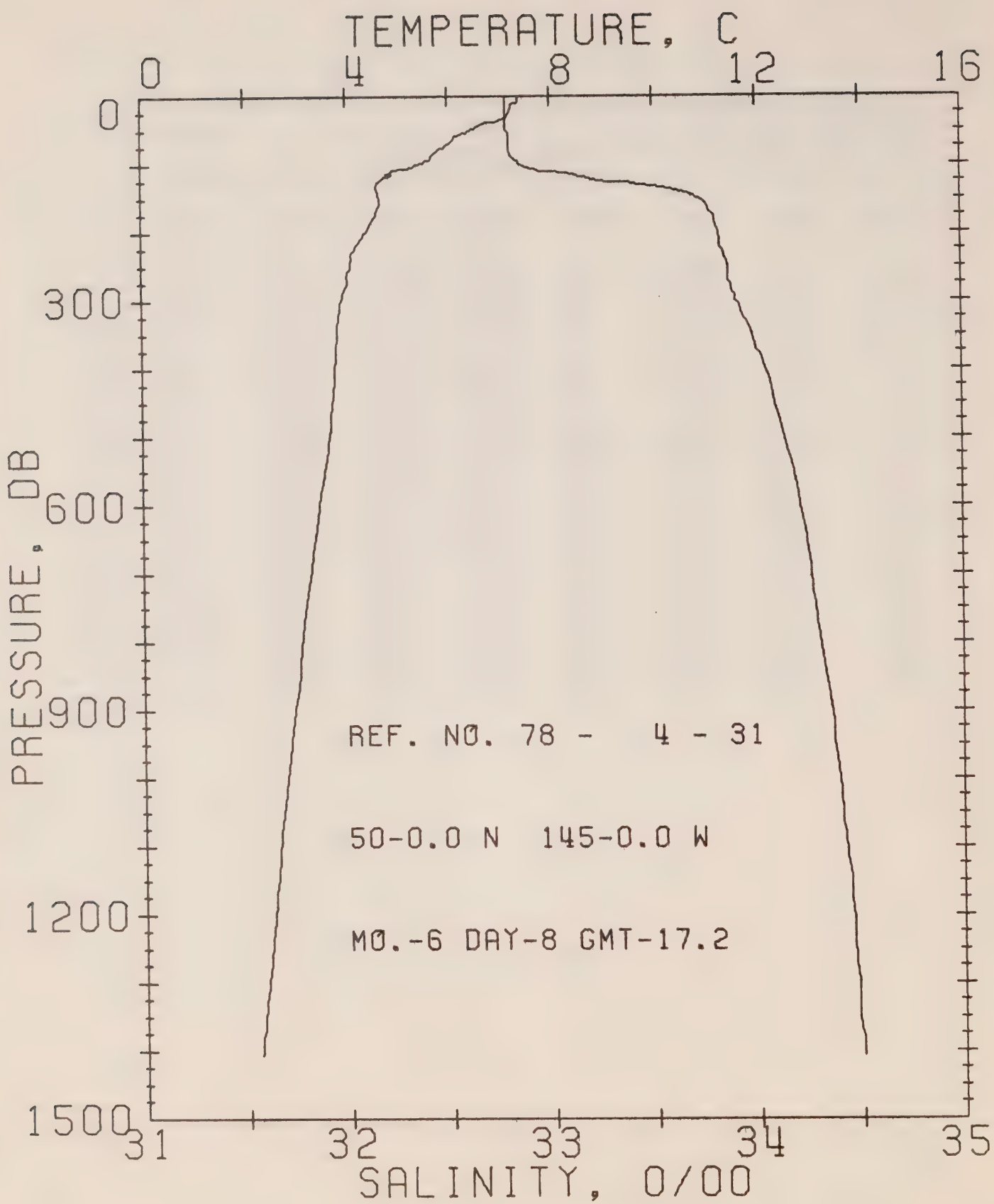
OFFSHORE OCEANOGRAPHY GROUP
REFERENCE NO. 78- 4- 28 DATE 5/ 6/78 STATION P
POSITION 50- 0.0N, 145- 0.0W GMT 17.3
RESULTS OF STP CAST 173 POINTS TAKEN FROM ANALOG TRACE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	DELTA D	POT. EN	SOUND
0	7.25	32.81	0	25.69	231.5	0.0	0.0	1477.
10	7.24	32.81	10	25.69	231.7	0.23	0.01	1477.
20	7.24	32.81	20	25.69	231.8	0.46	0.05	1477.
30	6.57	32.81	30	25.78	223.4	0.69	0.11	1475.
50	6.20	32.81	50	25.82	219.1	1.13	0.29	1474.
75	5.60	32.81	75	25.90	212.4	1.67	0.63	1472.
100	4.84	33.02	99	26.15	188.5	2.19	1.09	1469.
125	4.58	33.60	124	26.64	142.5	2.59	1.54	1469.
150	4.62	33.78	149	26.77	129.8	2.93	2.02	1470.
175	4.41	33.82	174	26.83	124.7	3.24	2.54	1470.
200	4.26	33.83	199	26.85	122.6	3.55	3.13	1470.
225	4.09	33.84	223	26.88	120.2	3.86	3.79	1469.
250	4.00	33.86	248	26.90	118.1	4.15	4.51	1469.
300	3.88	33.92	298	26.96	112.7	4.73	6.13	1470.
400	3.74	34.04	397	27.07	103.2	5.82	9.99	1471.
500	3.65	34.13	496	27.15	96.5	6.82	14.57	1472.
600	3.53	34.19	595	27.21	91.3	7.75	19.83	1474.
800	3.12	34.32	793	27.35	78.8	9.45	31.91	1475.
1000	2.83	34.39	990	27.44	71.5	10.96	45.69	1477.
1200	2.55	34.45	1188	27.51	65.3	12.33	61.04	1480.


TEMPERATURE, C
0
4
8
12
16
0
300
600
900
1200
1500
PRESSURE, DB
REF. NØ. 78 - 4 - 29
50-0.0 N 145-0.0 W
MØ.-6 DAY-6 GMT-17.2
31
32
33
34
35
SALINITY, O/OO

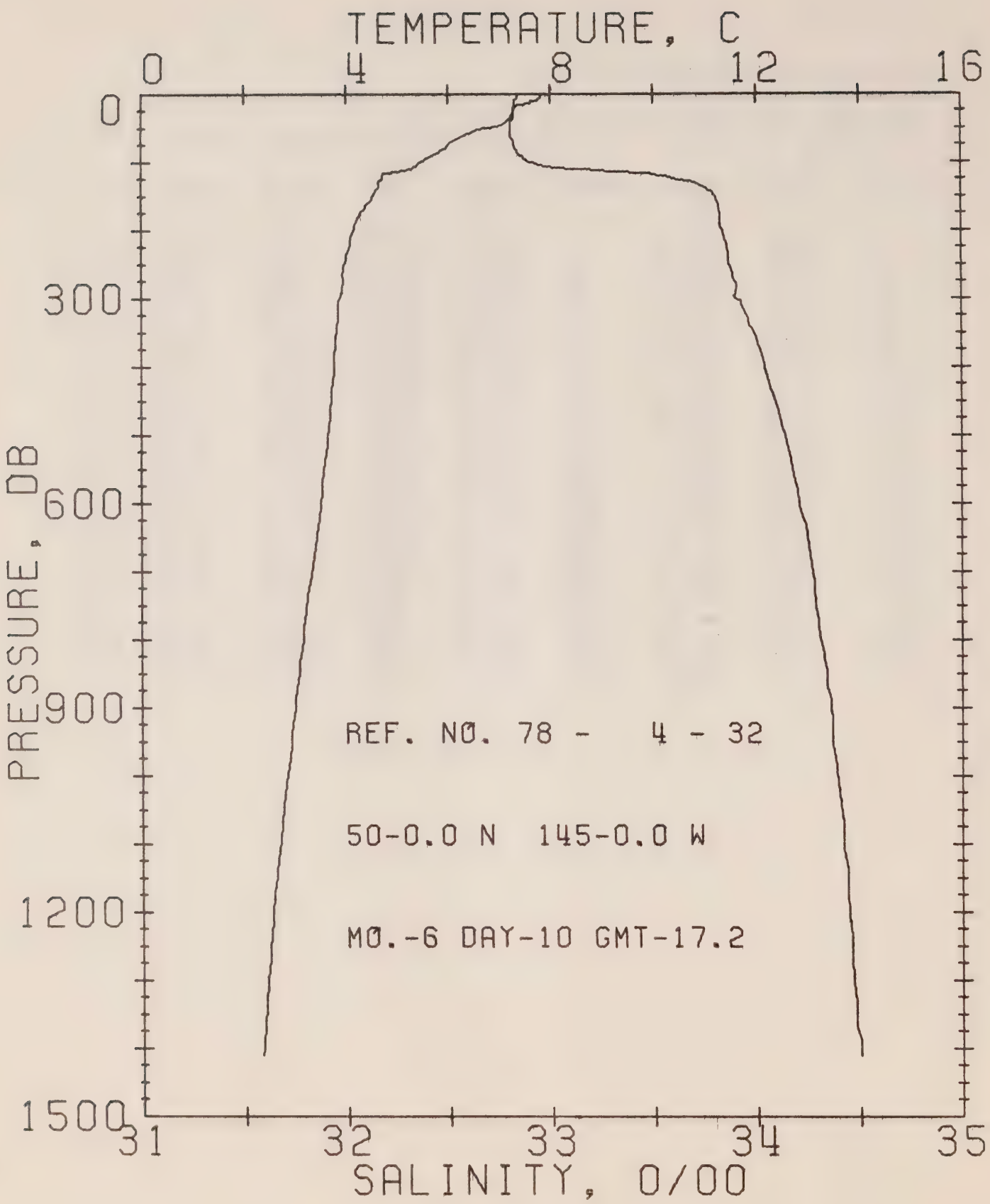
OFFSHORE OCEANOGRAPHY GROUP
REFERENCE NO. 78- 4- 29 DATE 6/ 6/78 STATION P
POSITION 50- 0.0N, 145- 0.0W GMT 17.2
RESULTS OF STP CAST 184 POINTS TAKEN FROM ANALOG TRACE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	DELTA D	POT. EN	SOUND
0	7.16	32.81	0	25.70	230.3	0.0	0.0	1477.
10	7.16	32.82	10	25.71	229.9	0.23	0.01	1477.
20	7.18	32.81	20	25.70	231.0	0.46	0.05	1477.
30	7.16	32.81	30	25.70	230.9	0.69	0.11	1477.
50	6.36	32.81	50	25.80	221.1	1.14	0.29	1474.
75	5.67	32.82	75	25.90	212.1	1.68	0.63	1472.
100	4.74	33.12	99	26.24	180.0	2.19	1.08	1469.
125	4.61	33.62	124	26.65	141.0	2.57	1.52	1470.
150	4.63	33.76	149	26.76	131.3	2.91	1.99	1470.
175	4.46	33.82	174	26.82	125.3	3.23	2.52	1470.
200	4.30	33.83	199	26.85	122.9	3.54	3.12	1470.
225	4.16	33.84	223	26.87	121.3	3.85	3.78	1470.
250	4.05	33.86	248	26.90	118.6	4.15	4.51	1470.
300	3.90	33.91	298	26.95	113.6	4.73	6.14	1470.
400	3.79	34.02	397	27.06	104.8	5.82	10.01	1471.
500	3.68	34.12	496	27.15	97.1	6.82	14.62	1473.
600	3.51	34.20	595	27.22	90.4	7.76	19.87	1474.
800	3.15	34.30	793	27.34	80.1	9.45	31.90	1475.
1000	2.88	34.38	990	27.42	73.0	10.97	45.81	1478.
1200	2.58	34.45	1188	27.51	65.5	12.35	61.25	1480.


TEMPERATURE, C
0
4
8
12
16
0
300
600
900
1200
1500
PRESSURE, DB
REF. NØ. 78 - 4 - 31
50-0.0 N 145-0.0 W
MØ.-6 DAY-8 GMT-17.2
31
32
33
34
35
SALINITY, 0/00

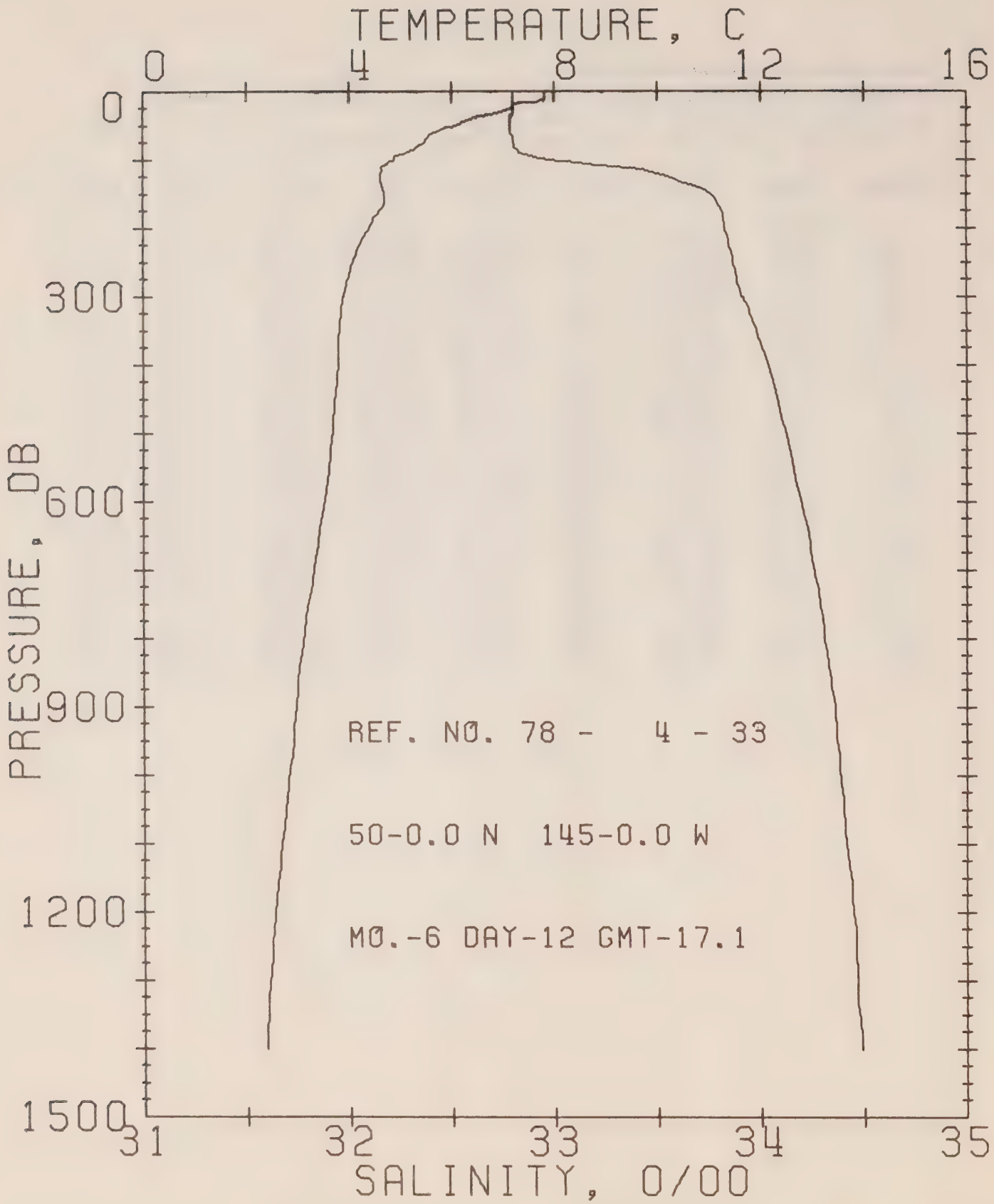
OFFSHORE OCEANOGRAPHY GROUP
REFERENCE NO. 78- 4- 31 DATE 8/ 6/78 STATION P
POSITION 50- 0.0N, 145- 0.0W GMT 17.2
RESULTS OF STP CAST 180 POINTS TAKEN FROM ANALOG TRACE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	DELTA D	POT. EN	SOUND
0	7.40	32.79	0	25.65	234.9	0.0	0.0	1478.
10	7.35	32.79	10	25.66	234.7	0.23	0.01	1478.
20	7.23	32.79	20	25.67	233.1	0.47	0.05	1477.
30	7.17	32.79	30	25.68	232.6	0.70	0.11	1477.
50	6.43	32.79	50	25.78	223.4	1.16	0.29	1475.
75	5.93	32.80	75	25.85	216.9	1.71	0.64	1473.
100	5.39	32.86	99	25.96	206.5	2.24	1.12	1471.
125	4.64	33.29	124	26.39	166.3	2.71	1.65	1469.
150	4.66	33.72	149	26.72	134.5	3.07	2.16	1470.
175	4.57	33.79	174	26.79	128.2	3.40	2.70	1470.
200	4.36	33.82	199	26.84	124.3	3.72	3.31	1470.
225	4.14	33.84	223	26.87	121.1	4.02	3.97	1470.
250	4.07	33.87	248	26.90	118.3	4.32	4.69	1470.
300	3.89	33.90	298	26.95	114.4	4.90	6.33	1470.
400	3.77	34.04	397	27.08	103.0	5.99	10.18	1471.
500	3.65	34.13	496	27.16	96.0	6.98	14.74	1472.
600	3.45	34.21	595	27.24	88.9	7.90	19.90	1473.
800	3.09	34.31	793	27.35	79.4	9.58	31.83	1475.
1000	2.79	34.39	990	27.45	70.7	11.08	45.52	1477.
1200	2.51	34.46	1188	27.52	64.2	12.42	60.59	1479.


TEMPERATURE, C
0
4
8
12
16
0
300
600
900
1200
1500
PRESSURE, DB
REF. NO. 78 - 4 - 32
50-0.0 N 145-0.0 W
MO.-6 DAY-10 GMT-17.2
31
32
33
34
35
SALINITY, O/OO

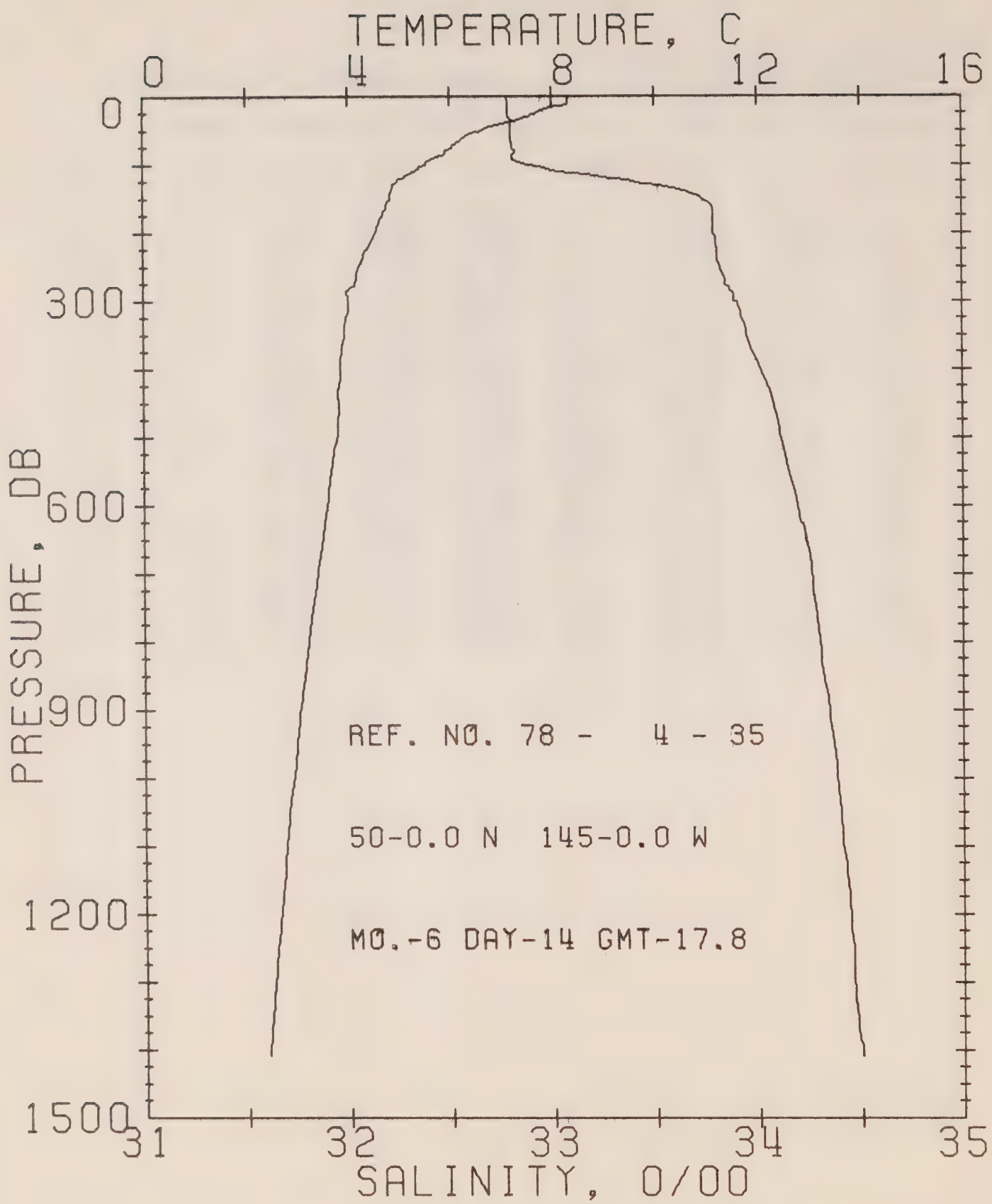
OFFSHORE OCEANOGRAPHY GROUP
REFERENCE NO. 78- 4- 32 DATE 10/ 6/78 STATION P
POSITION 50- 0.0N, 145- 0.0W GMT 17.2
RESULTS OF STP CAST 178 POINTS TAKEN FROM ANALOG TRACE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	DELTA D	POT. EN	SOUND
0	7.81	32.84	0	25.63	236.6	0.0	0.0	1479.
10	7.75	32.83	10	25.63	237.0	0.24	0.01	1479.
20	7.30	32.83	20	25.69	231.3	0.47	0.05	1478.
30	7.25	32.82	30	25.69	231.3	0.70	0.11	1478.
50	6.76	32.81	50	25.75	226.1	1.16	0.29	1476.
75	5.98	32.82	75	25.86	215.8	1.71	0.64	1473.
100	5.46	32.90	99	25.98	204.4	2.24	1.11	1472.
125	4.69	33.61	124	26.64	142.6	2.68	1.61	1470.
150	4.53	33.80	149	26.80	127.3	3.01	2.07	1470.
175	4.28	33.83	174	26.85	122.9	3.32	2.59	1469.
200	4.13	33.84	199	26.87	120.6	3.62	3.17	1469.
225	4.05	33.86	223	26.90	118.3	3.92	3.82	1469.
250	3.96	33.87	248	26.92	116.9	4.22	4.53	1469.
300	3.88	33.90	298	26.95	114.3	4.79	6.14	1470.
400	3.75	34.04	397	27.07	103.3	5.87	9.96	1471.
500	3.64	34.14	496	27.16	95.3	6.86	14.51	1472.
600	3.49	34.21	595	27.23	89.4	7.78	19.67	1473.
800	3.14	34.31	793	27.35	79.5	9.46	31.60	1475.
1000	2.83	34.39	990	27.44	71.4	10.96	45.33	1477.
1200	2.54	34.45	1188	27.51	65.2	12.32	60.57	1480.


TEMPERATURE, C
0
4
8
12
16
0
300
600
900
1200
1500
PRESSURE, DB
REF. NO. 78 - 4 - 33
50-0.0 N 145-0.0 W
MO.-6 DAY-12 GMT-17.1
31
32
33
34
35
SALINITY, O/OO

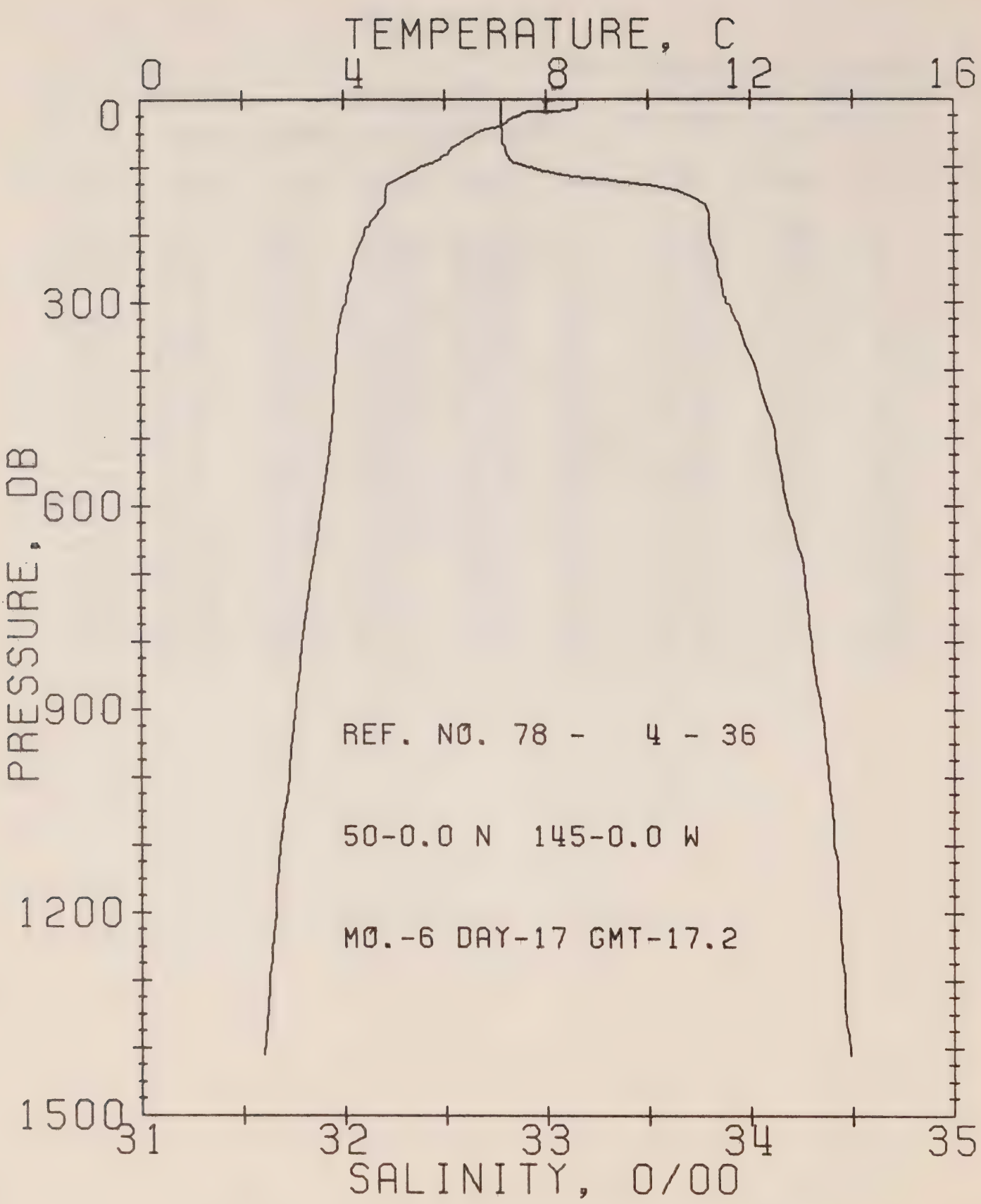
OFFSHORE OCEANOGRAPHY GROUP
REFERENCE NO. 78- 4- 33 DATE 12/ 6/78 STATION P
POSITION 50- 0.0N, 145- 0.0W GMT 17.1
RESULTS OF STP CAST 175 POINTS TAKEN FROM ANALOG TRACE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	DELTA D	POT. EN	SOUND
0	7.81	32.80	0	25.60	239.6	0.0	0.0	1479.
10	7.80	32.80	10	25.60	239.9	0.24	0.01	1479.
20	7.19	32.80	20	25.69	232.0	0.48	0.05	1477.
30	6.98	32.80	30	25.71	229.3	0.71	0.11	1477.
50	6.11	32.79	50	25.82	219.6	1.16	0.29	1473.
75	5.43	32.80	75	25.91	211.2	1.69	0.63	1471.
100	4.87	32.96	99	26.10	193.4	2.20	1.09	1469.
125	4.61	33.57	124	26.61	145.0	2.62	1.56	1470.
150	4.70	33.76	149	26.75	132.3	2.96	2.04	1471.
175	4.59	33.81	174	26.81	127.1	3.29	2.58	1471.
200	4.37	33.83	199	26.84	123.7	3.60	3.18	1470.
225	4.19	33.85	223	26.88	120.6	3.90	3.84	1470.
250	4.05	33.87	248	26.91	117.8	4.20	4.56	1470.
300	3.89	33.91	298	26.96	113.5	4.78	6.18	1470.
400	3.77	34.04	397	27.07	103.6	5.86	10.02	1471.
500	3.67	34.12	496	27.15	96.9	6.86	14.61	1472.
600	3.50	34.19	595	27.22	90.7	7.80	19.87	1473.
800	3.10	34.31	793	27.35	79.1	9.49	31.86	1475.
1000	2.82	34.39	990	27.44	71.8	10.99	45.60	1477.
1200	2.53	34.45	1188	27.51	65.1	12.36	60.92	1480.


TEMPERATURE, C
0
4
8
12
16
0
300
600
900
1200
1500
PRESSURE, DB
REF. NO. 78 - 4 - 35
50-0.0 N 145-0.0 W
MO.-6 DAY-14 GMT-17.8
31
32
33
34
35
SALINITY, O/OO

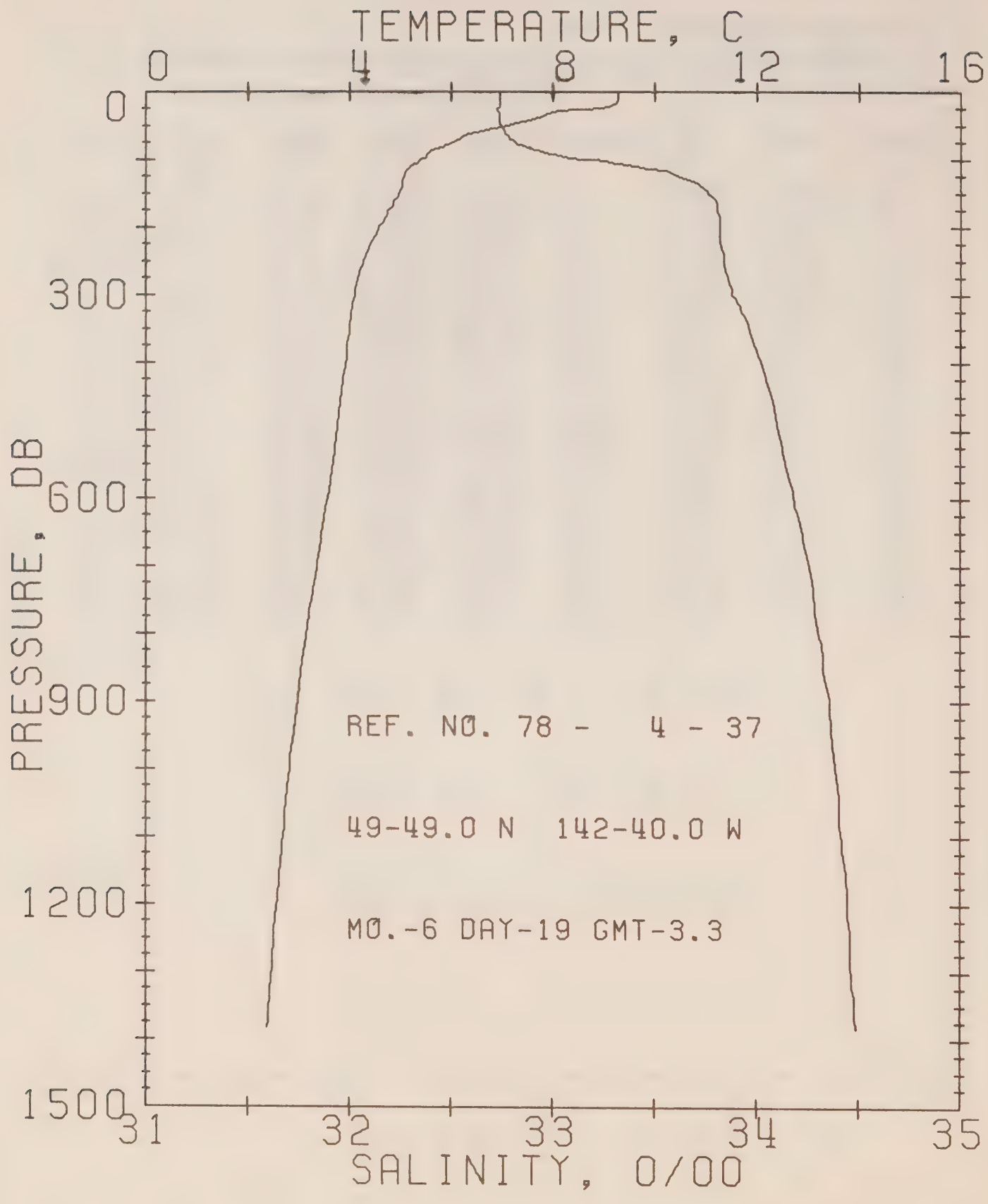
OFFSHORE OCEANOGRAPHY GROUP
REFERENCE NO. 78- 4- 35 DATE 14/ 6/78 STATION P
POSITION 50- 0.0N, 145- 0.0W GMT 17.8
RESULTS OF STP CAST 182 POINTS TAKEN FROM ANALOG TRACE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	DELTA D	POT. EN	SOUND
0	8.32	32.78	0	25.51	248.3	0.0	0.0	1481.
10	8.31	32.79	10	25.52	247.7	0.25	0.01	1481.
20	7.83	32.79	20	25.59	241.2	0.49	0.05	1480.
30	7.55	32.79	30	25.63	237.6	0.73	0.11	1479.
50	6.66	32.80	50	25.76	225.5	1.19	0.30	1476.
75	6.04	32.81	75	25.84	217.5	1.75	0.65	1474.
100	5.51	32.88	99	25.96	206.4	2.28	1.13	1472.
125	4.95	33.40	124	26.44	161.1	2.74	1.65	1471.
150	4.83	33.73	149	26.72	135.5	3.11	2.16	1471.
175	4.66	33.79	174	26.78	129.5	3.43	2.70	1471.
200	4.53	33.79	199	26.79	128.4	3.76	3.32	1471.
225	4.35	33.81	223	26.83	125.3	4.07	4.01	1470.
250	4.20	33.82	248	26.85	123.1	4.38	4.76	1470.
300	4.00	33.89	298	26.93	116.2	4.98	6.43	1470.
400	3.84	34.02	397	27.04	106.0	6.09	10.38	1471.
500	3.77	34.11	496	27.13	98.8	7.11	15.04	1473.
600	3.57	34.20	595	27.21	91.2	8.06	20.36	1474.
800	3.20	34.30	793	27.33	80.9	9.77	32.51	1476.
1000	2.89	34.38	990	27.43	72.8	11.30	46.53	1478.
1200	2.63	34.45	1188	27.50	66.4	12.69	62.07	1480.


TEMPERATURE, C
0
4
8
12
16
0
300
600
900
1200
1500
PRESSURE, DB
REF. NØ. 78 - 4 - 36
50-0.0 N 145-0.0 W
MØ.-6 DAY-17 GMT-17.2
31
32
33
34
35
SALINITY, 0/00

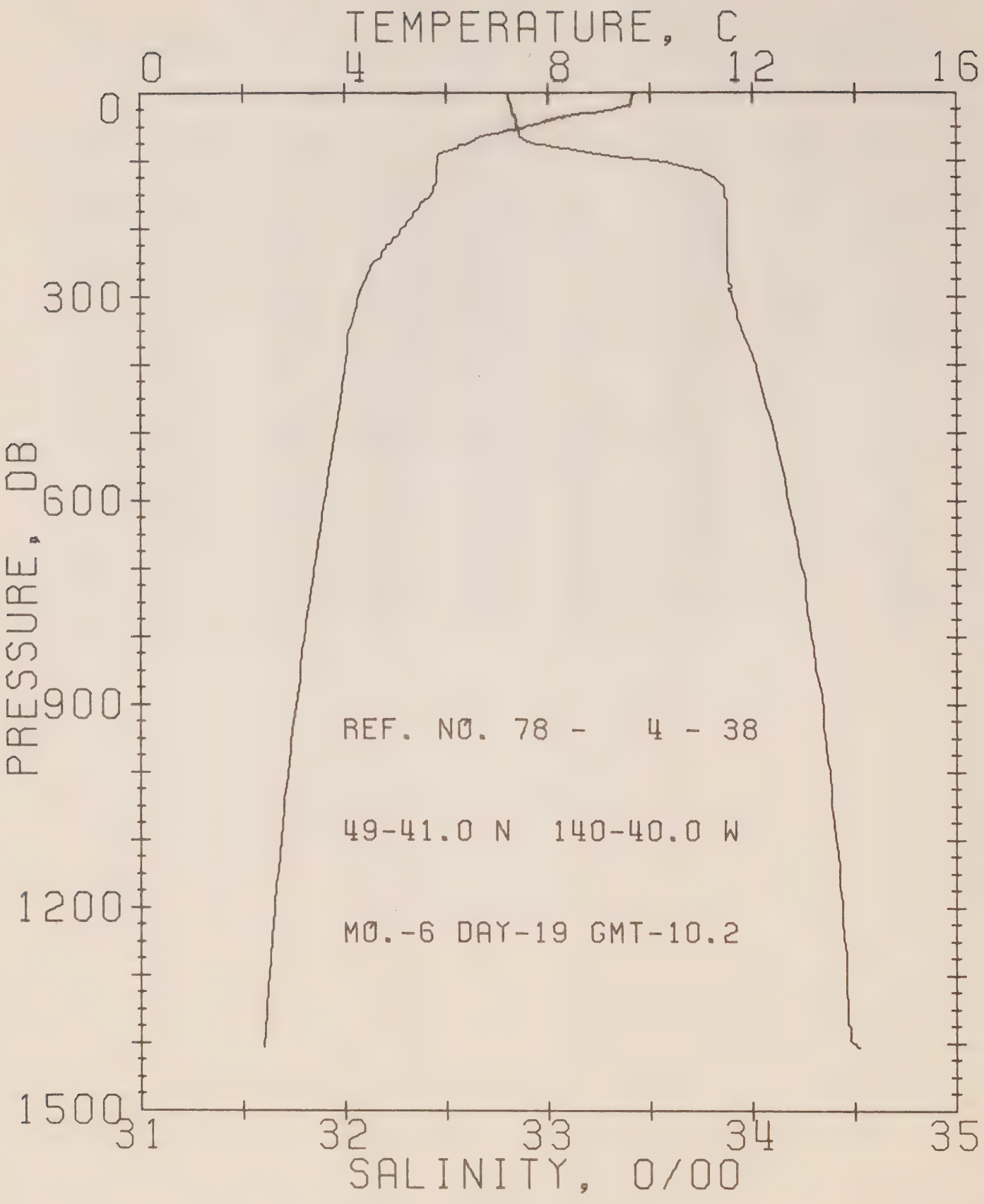
OFFSHORE OCEANOGRAPHY GROUP
REFERENCE NO. 78- 4- 36 DATE 17/ 6/78 STATION P
POSITION 50- 0.0N, 145- 0.0W GMT 17.2
RESULTS OF STP CAST 187 POINTS TAKEN FROM ANALOG TRACE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	DELTA D	POT. EN	SOUND
0	8.61	32.78	0	25.47	252.4	0.0	0.0	1482.
10	8.60	32.78	10	25.47	252.6	0.25	0.01	1482.
20	7.57	32.78	20	25.62	238.4	0.50	0.05	1479.
30	7.29	32.78	30	25.66	234.8	0.74	0.11	1478.
50	6.66	32.79	50	25.75	226.3	1.20	0.30	1476.
75	6.11	32.80	75	25.83	219.1	1.76	0.65	1474.
100	5.54	32.92	99	25.99	203.9	2.29	1.13	1472.
125	4.88	33.46	124	26.49	156.2	2.75	1.66	1470.
150	4.82	33.75	149	26.73	134.0	3.11	2.15	1471.
175	4.59	33.80	174	26.80	128.1	3.43	2.69	1471.
200	4.38	33.80	199	26.82	126.0	3.75	3.30	1470.
225	4.26	33.82	223	26.85	123.3	4.06	3.97	1470.
250	4.16	33.84	248	26.87	121.2	4.37	4.71	1470.
300	4.04	33.88	298	26.92	117.3	4.96	6.38	1470.
400	3.83	34.03	397	27.06	104.7	6.06	10.30	1471.
500	3.73	34.12	496	27.14	97.6	7.08	14.93	1473.
600	3.56	34.18	595	27.20	92.4	8.03	20.26	1474.
800	3.17	34.30	793	27.34	80.7	9.73	32.40	1475.
1000	2.89	34.38	990	27.43	72.8	11.26	46.40	1478.
1200	2.63	34.44	1188	27.50	66.9	12.65	61.94	1480.


TEMPERATURE, C
0
4
8
12
16
0
300
600
900
1200
1500
PRESSURE, DB
REF. NO. 78 - 4 - 37
49-49.0 N 142-40.0 W
MO.-6 DAY-19 GMT-3.3
31
32
33
34
35
SALINITY, O/OO

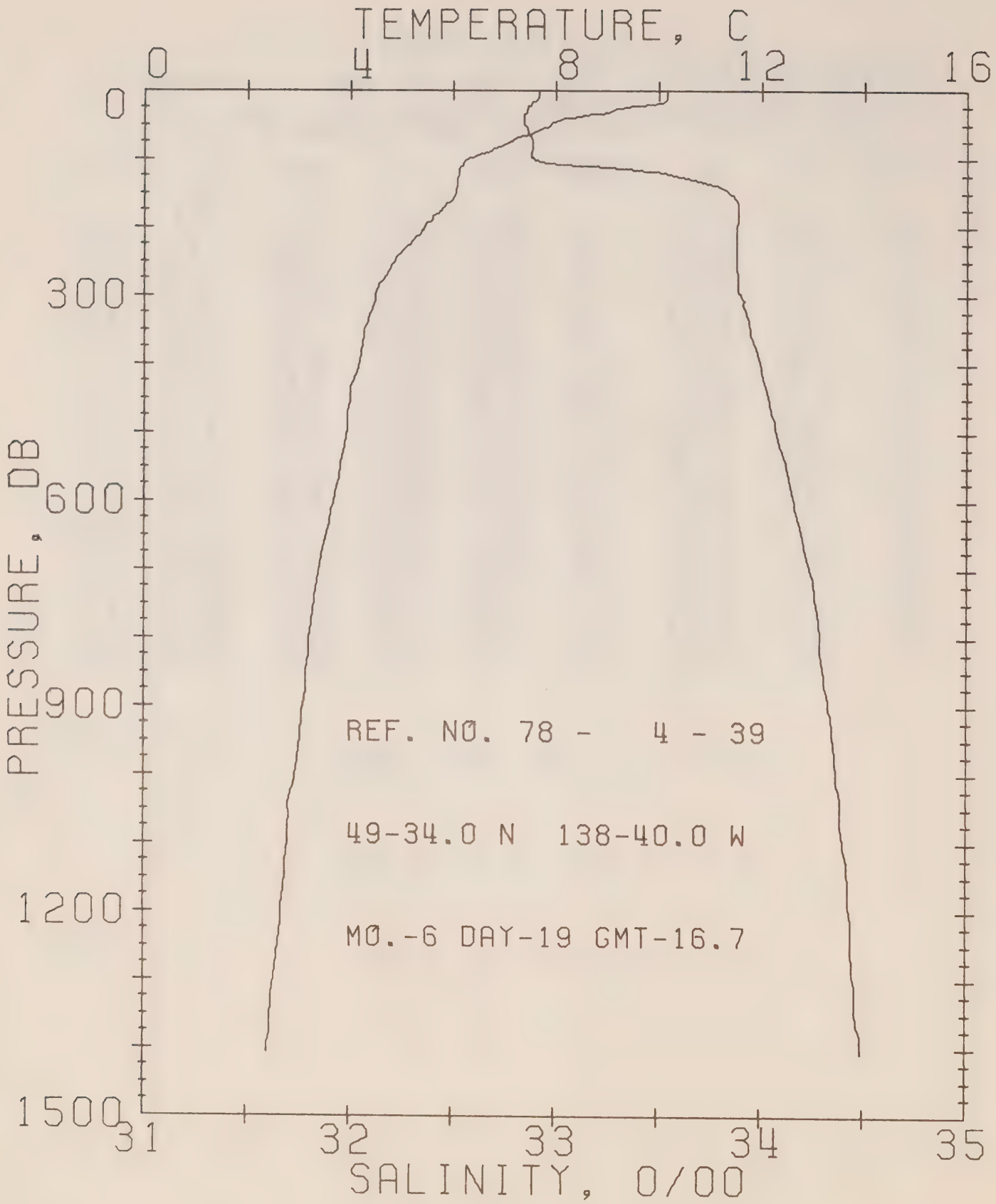
OFFSHORE OCEANOGRAPHY GROUP
REFERENCE NO. 78- 4- 37 DATE 19/ 6/78 STATION 12
POSITION 49-49.0N, 142-40.0W GMT 3.3
RESULTS OF STP CAST 160 POINTS TAKEN FROM ANALOG TRACE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	DELTA D	POT. EN	SOUND
0	9.28	32.74	0	25.33	265.3	0.0	0.0	1485.
10	9.29	32.74	10	25.33	265.8	0.27	0.01	1485.
20	9.17	32.74	20	25.35	264.2	0.53	0.05	1485.
30	8.06	32.73	30	25.51	248.8	0.79	0.12	1481.
50	7.12	32.74	50	25.65	235.6	1.27	0.32	1477.
75	6.02	32.82	75	25.85	216.8	1.84	0.67	1473.
100	5.41	33.16	99	26.20	184.3	2.34	1.13	1472.
125	5.06	33.62	124	26.60	146.2	2.75	1.59	1471.
150	4.97	33.76	149	26.72	134.9	3.10	2.07	1472.
175	4.77	33.81	174	26.78	129.2	3.42	2.62	1471.
200	4.59	33.82	199	26.81	126.8	3.74	3.23	1471.
225	4.41	33.82	223	26.83	124.8	4.06	3.91	1471.
250	4.27	33.84	248	26.86	122.4	4.37	4.66	1471.
300	4.11	33.88	298	26.91	118.1	4.97	6.34	1471.
400	3.92	34.02	397	27.04	106.0	6.08	10.29	1472.
500	3.76	34.11	496	27.13	99.0	7.10	14.98	1473.
600	3.56	34.18	595	27.21	92.0	8.06	20.33	1474.
800	3.15	34.31	793	27.34	79.9	9.77	32.48	1475.
1000	2.82	34.39	990	27.44	71.3	11.27	46.27	1477.
1200	2.56	34.45	1188	27.51	65.4	12.64	61.57	1480.


TEMPERATURE, C
0
4
8
12
16
0
300
600
900
1200
1500
PRESSURE, DB
REF. NØ. 78 - 4 - 38
49-41.0 N 140-40.0 W
MØ.-6 DAY-19 GMT-10.2
31
32
33
34
35
SALINITY, 0/00

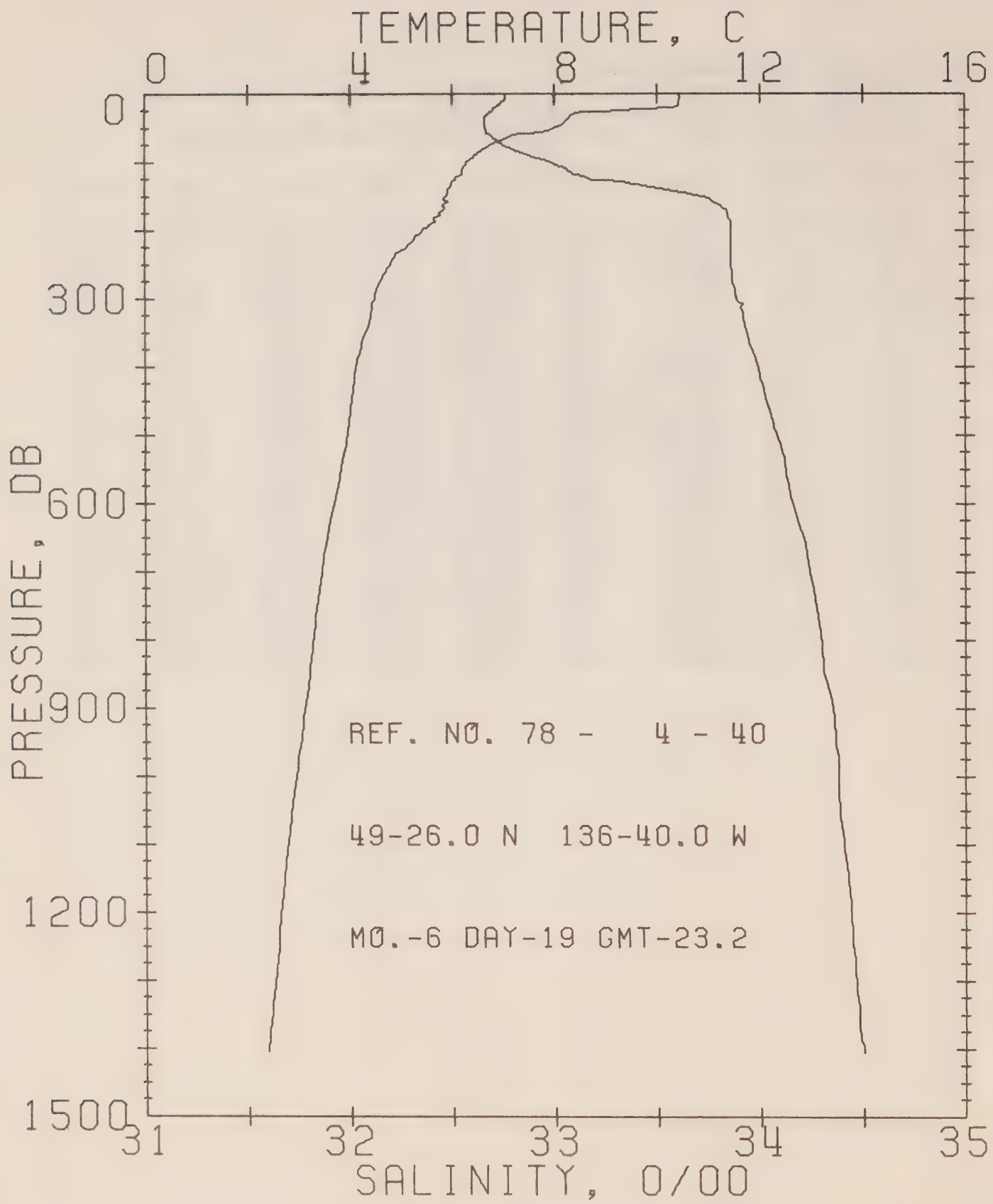
OFFSHORE OCEANOGRAPHY GROUP
REFERENCE NO. 78- 4- 38 DATE 19/ 6/78 STATION 11
POSITION 49-41.0N, 140-40.0W GMT 10.2
RESULTS OF STP CAST 212 POINTS TAKEN FROM ANALOG TRACE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	DELTA D	POT. EN	SOUND
0	9.67	32.81	0	25.32	266.1	0.0	0.0	1486.
10	9.64	32.81	10	25.33	266.0	0.27	0.01	1486.
20	9.54	32.82	20	25.35	263.9	0.53	0.05	1486.
30	8.89	32.83	30	25.46	253.5	0.79	0.12	1484.
50	7.58	32.85	50	25.67	233.7	1.27	0.32	1479.
75	6.39	32.95	75	25.91	211.3	1.83	0.67	1475.
100	5.84	33.51	99	26.42	163.1	2.30	1.09	1474.
125	5.81	33.81	124	26.66	140.7	2.67	1.51	1475.
150	5.72	33.87	149	26.72	135.4	3.02	1.99	1475.
175	5.37	33.88	174	26.77	130.8	3.35	2.54	1474.
200	5.11	33.88	199	26.80	128.1	3.67	3.16	1473.
225	4.83	33.88	223	26.83	125.2	3.99	3.85	1472.
250	4.57	33.88	248	26.86	122.6	4.30	4.60	1472.
300	4.27	33.90	298	26.91	118.3	4.90	6.29	1471.
400	4.01	34.02	397	27.03	107.6	6.03	10.31	1472.
500	3.81	34.10	496	27.12	99.8	7.07	15.07	1473.
600	3.60	34.17	595	27.19	93.2	8.03	20.45	1474.
800	3.19	34.29	793	27.32	81.7	9.77	32.81	1476.
1000	2.89	34.38	990	27.43	72.9	11.31	46.53	1478.
1200	2.61	34.44	1188	27.50	66.7	12.70	62.52	1480.


TEMPERATURE, C
0
4
8
12
16
0
300
600
900
1200
1500
PRESSURE, DB
REF. NØ. 78 - 4 - 39
49-34.0 N 138-40.0 W
MØ.-6 DAY-19 GMT-16.7
31
32
33
34
35
SALINITY, 0/00

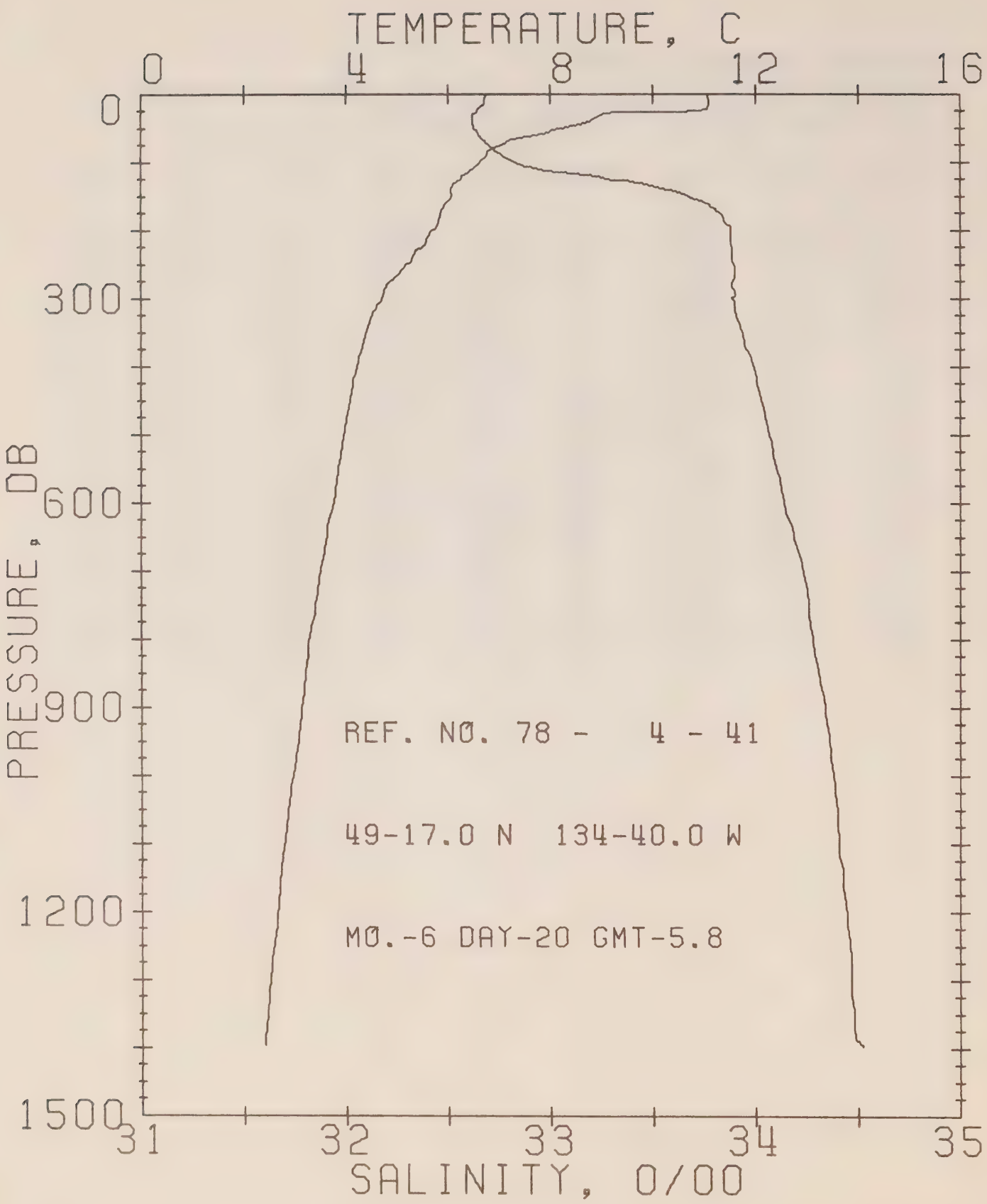
OFFSHORE OCEANOGRAPHY GROUP
REFERENCE NO. 78- 4- 39 DATE 19/ 6/78 STATION 10
POSITION 49-34.0N, 138-40.0W GMT 16.7
RESULTS OF STP CAST 216 POINTS TAKEN FROM ANALOG TRACE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	DELTA D	POT. EN	SOUND
0	10.15	32.92	0	25.33	265.5	0.0	0.0	1488.
10	10.15	32.92	10	25.33	265.9	0.27	0.01	1488.
20	9.85	32.88	20	25.35	264.3	0.53	0.05	1487.
30	9.08	32.86	30	25.46	254.1	0.79	0.12	1485.
50	7.90	32.85	50	25.63	238.2	1.28	0.32	1481.
75	7.10	32.89	75	25.77	224.8	1.86	0.69	1478.
100	6.32	32.89	99	25.87	215.1	2.41	1.18	1475.
125	6.09	33.59	124	26.46	160.2	2.88	1.71	1476.
150	6.04	33.85	149	26.66	140.7	3.25	2.23	1476.
175	5.76	33.89	174	26.73	134.7	3.59	2.80	1475.
200	5.44	33.88	199	26.76	132.0	3.93	3.44	1475.
225	5.14	33.88	223	26.80	128.7	4.25	4.14	1474.
250	4.84	33.88	248	26.83	125.6	4.57	4.91	1473.
300	4.48	33.90	298	26.89	120.5	5.19	6.64	1472.
400	4.17	34.00	397	26.99	110.9	6.34	10.75	1473.
500	3.93	34.08	496	27.08	103.2	7.41	15.64	1473.
600	3.68	34.16	595	27.17	95.2	8.40	21.19	1474.
800	3.21	34.29	793	27.32	81.9	10.15	33.65	1476.
1000	2.94	34.37	990	27.41	74.3	11.72	47.98	1478.
1200	2.67	34.43	1188	27.49	67.7	13.13	63.79	1480.


TEMPERATURE, C
0
4
8
12
16
0
300
600
900
1200
1500
PRESSURE, DB
REF. NØ. 78 - 4 - 40
49-26.0 N 136-40.0 W
MØ.-6 DAY-19 GMT-23.2
31
32
33
34
35
SALINITY, 0/00

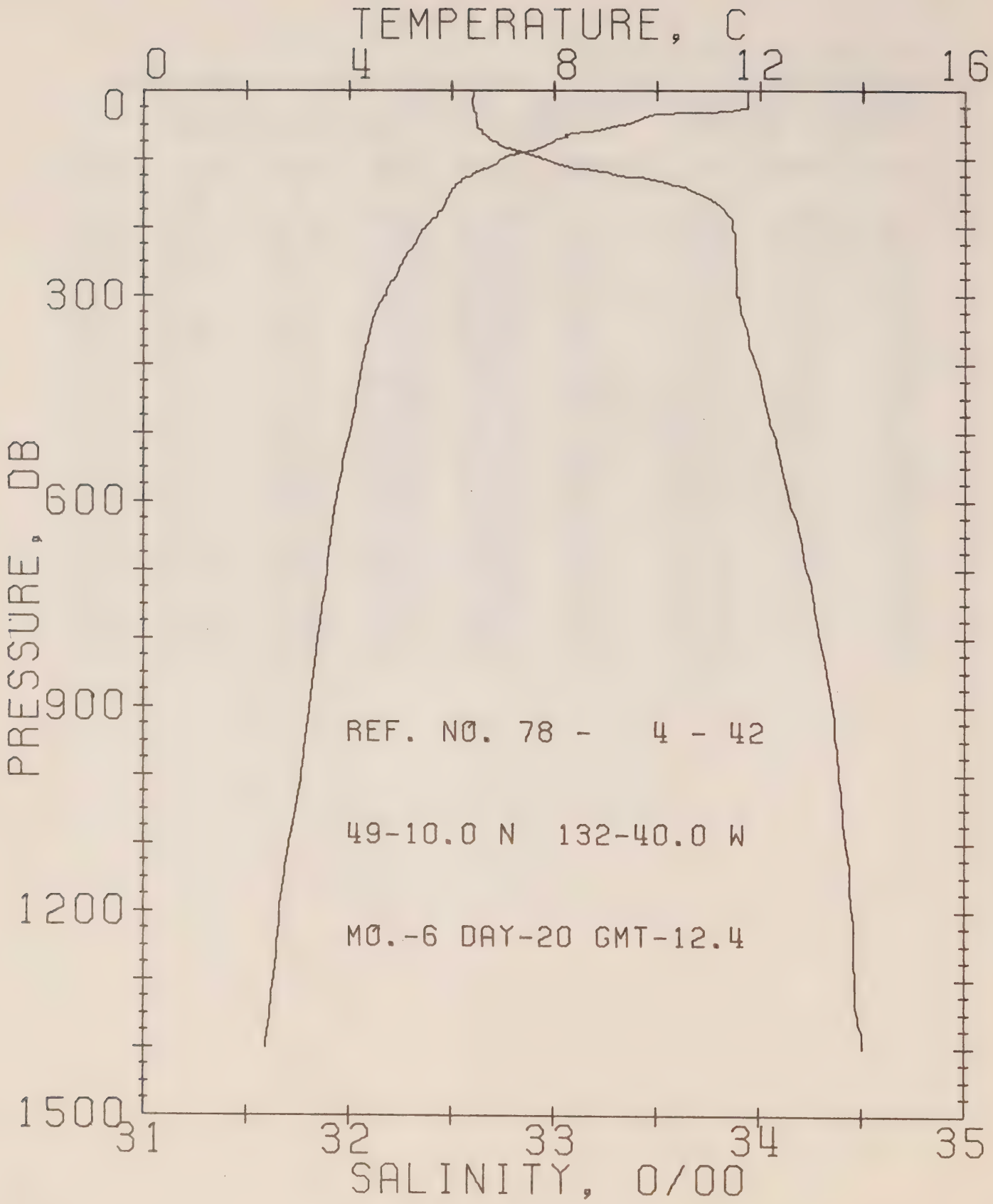
OFFSHORE OCEANOGRAPHY GROUP
REFERENCE NO. 78- 4- 40 DATE 19/ 6/78 STATION 9
POSITION 49-26.0N, 136-40.0W GMT 23.2
RESULTS OF STP CAST 183 POINTS TAKEN FROM ANALOG TRACE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	DELTA D	POT. EN	SOUND
0	10.44	32.77	0	25.16	281.3	0.0	0.0	1489.
10	10.44	32.75	10	25.15	283.2	0.28	0.01	1489.
20	10.33	32.71	20	25.13	284.6	0.57	0.06	1489.
30	8.40	32.68	30	25.42	257.7	0.83	0.13	1482.
50	8.01	32.66	50	25.46	253.7	1.35	0.33	1481.
75	6.72	32.75	75	25.71	230.3	1.95	0.72	1476.
100	6.27	32.99	99	25.96	207.2	2.50	1.21	1475.
125	6.06	33.19	124	26.14	190.0	3.00	1.78	1475.
150	5.88	33.72	149	26.58	148.7	3.42	2.36	1475.
175	5.77	33.84	174	26.69	138.3	3.77	2.95	1475.
200	5.42	33.86	199	26.75	133.1	4.11	3.60	1474.
225	5.06	33.86	223	26.79	129.3	4.44	4.31	1473.
250	4.76	33.86	248	26.82	126.2	4.76	5.08	1473.
300	4.48	33.89	298	26.88	121.3	5.38	6.81	1472.
400	4.10	33.99	397	27.00	110.7	6.53	10.93	1472.
500	3.94	34.08	496	27.09	102.8	7.60	15.83	1474.
600	3.67	34.16	595	27.18	95.1	8.59	21.36	1474.
800	3.27	34.30	793	27.32	81.8	10.34	33.78	1476.
1000	2.93	34.38	990	27.42	73.4	11.88	47.92	1478.
1200	2.62	34.44	1188	27.50	66.7	13.28	63.61	1480.


TEMPERATURE, C
0
4
8
12
16
0
300
600
900
1200
1500
PRESSURE, DB
REF. NØ. 78 - 4 - 41
49-17.0 N 134-40.0 W
MØ.-6 DAY-20 GMT-5.8
31
32
33
34
35
SALINITY, 0/00

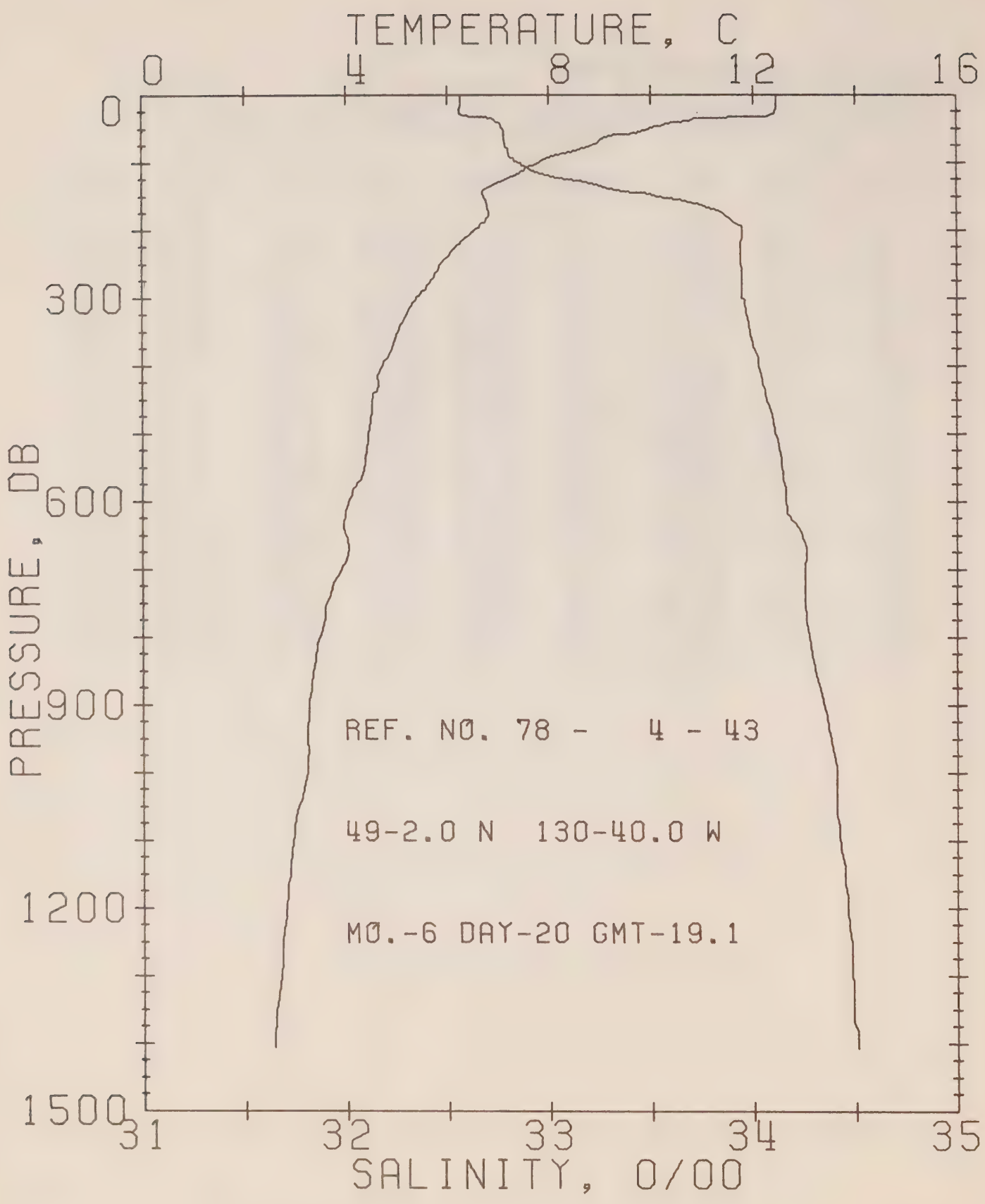
OFFSHORE OCEANOGRAPHY GROUP
REFERENCE NO. 78- 4- 41 DATE 20/ 6/78 STATION 8
POSITION 49-17.0N, 134-40.0W GMT 5.8
RESULTS OF STP CAST 198 POINTS TAKEN FROM ANALOG TRACE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	DELTA D	POT. EN	SOUND
0	11.07	32.69	0	24.99	297.7	0.0	0.0	1491.
10	11.10	32.68	10	24.98	299.3	0.30	0.02	1492.
20	11.07	32.66	20	24.96	300.7	0.60	0.06	1492.
30	9.01	32.62	30	25.28	270.7	0.88	0.13	1484.
50	8.23	32.63	50	25.41	259.1	1.42	0.35	1482.
75	7.04	32.70	75	25.63	237.9	2.04	0.74	1477.
100	6.61	32.83	99	25.79	222.9	2.61	1.26	1476.
125	6.21	33.31	124	26.22	182.8	3.13	1.85	1476.
150	6.05	33.67	149	26.52	154.1	3.54	2.42	1476.
175	5.85	33.83	174	26.67	140.0	3.91	3.03	1476.
200	5.70	33.88	199	26.73	135.1	4.25	3.69	1476.
225	5.47	33.89	223	26.77	131.8	4.59	4.41	1475.
250	5.20	33.90	248	26.80	128.4	4.91	5.20	1474.
300	4.69	33.89	298	26.86	123.7	5.54	6.95	1473.
400	4.21	33.99	397	26.99	111.8	6.71	11.13	1473.
500	3.96	34.07	496	27.07	104.1	7.79	16.07	1474.
600	3.75	34.14	595	27.15	97.2	8.79	21.69	1474.
800	3.26	34.28	793	27.31	83.1	10.58	34.37	1476.
1000	2.96	34.38	990	27.42	73.6	12.14	48.69	1478.
1200	2.66	34.45	1188	27.50	66.6	13.54	64.39	1480.


TEMPERATURE, C
0
4
8
12
16
0
300
600
900
1200
1500
PRESSURE, DB
REF. NO. 78 - 4 - 42
49-10.0 N 132-40.0 W
MO.-6 DAY-20 GMT-12.4
31
32
33
34
35
SALINITY, O/OO

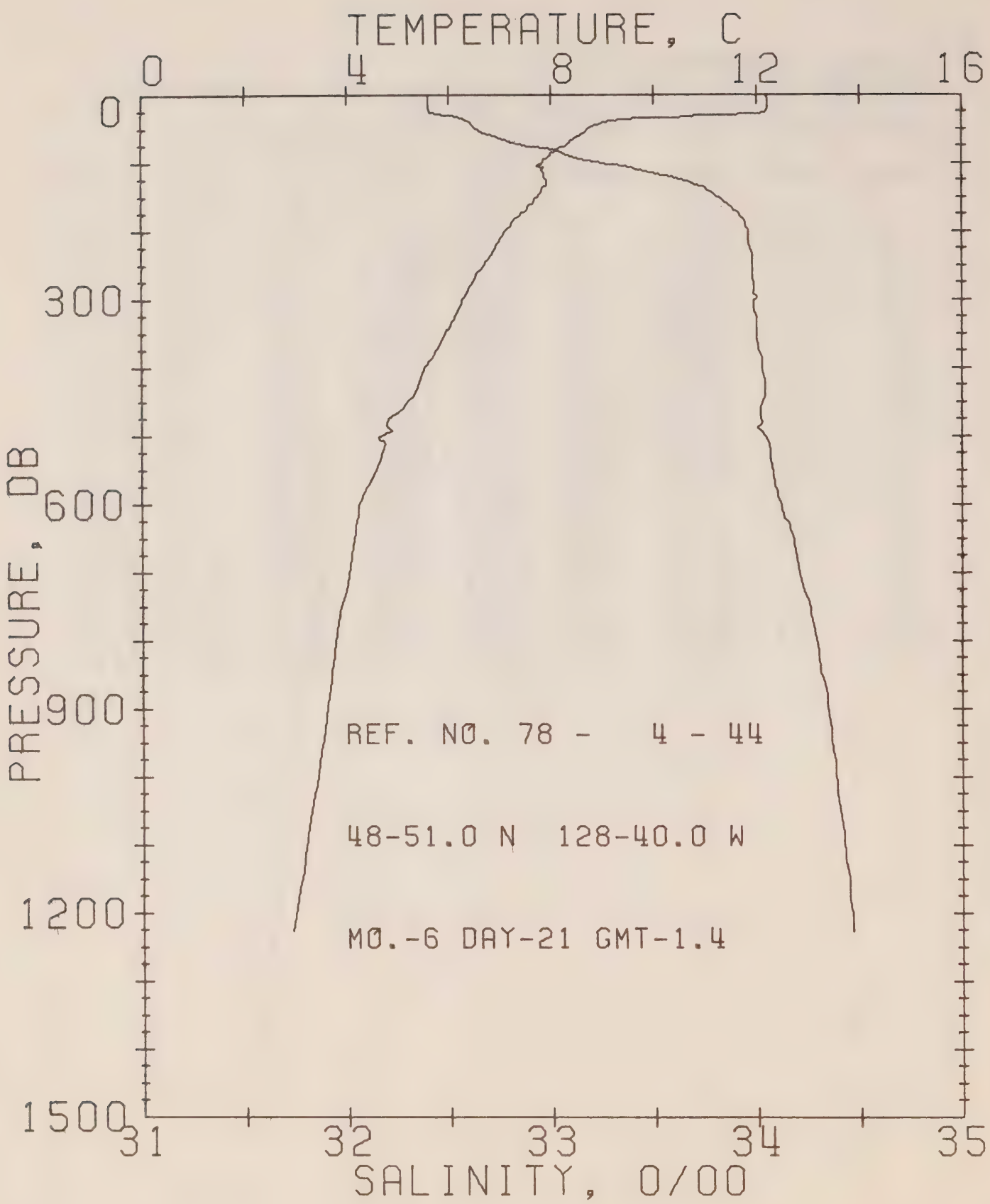
OFFSHORE OCEANOGRAPHY GROUP
REFERENCE NO. 78- 4- 42 DATE 20/ 6/78 STATION 7
POSITION 49-10.0N, 132-40.0W GMT 12.4
RESULTS OF STP CAST 202 POINTS TAKEN FROM ANALOG TRACE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	DELTA D	POT. EN	SOUND
0	11.76	32.61	0	24.80	315.5	0.0	0.0	1494.
10	11.76	32.61	10	24.80	316.0	0.32	0.02	1494.
20	11.77	32.60	20	24.79	317.1	0.63	0.06	1494.
30	11.35	32.61	30	24.88	309.2	0.95	0.14	1493.
50	9.31	32.63	50	25.24	275.0	1.52	0.38	1486.
75	7.96	32.72	75	25.51	249.1	2.17	0.79	1481.
100	6.98	32.95	99	25.84	218.7	2.76	1.32	1478.
125	6.35	33.37	124	26.25	180.0	3.27	1.90	1476.
150	5.97	33.69	149	26.55	151.5	3.67	2.46	1476.
175	5.78	33.83	174	26.68	139.4	4.04	3.06	1475.
200	5.49	33.87	199	26.75	133.2	4.38	3.71	1475.
225	5.27	33.88	223	26.78	130.3	4.70	4.42	1474.
250	5.04	33.88	248	26.81	127.9	5.03	5.20	1474.
300	4.71	33.89	298	26.85	123.9	5.65	6.96	1473.
400	4.25	33.98	397	26.97	113.1	6.83	11.15	1473.
500	4.00	34.07	496	27.07	104.7	7.92	16.14	1474.
600	3.75	34.14	595	27.16	96.9	8.93	21.78	1474.
800	3.39	34.30	793	27.31	83.3	10.72	34.50	1476.
1000	3.07	34.39	990	27.42	74.2	12.28	48.79	1478.
1200	2.65	34.45	1188	27.50	66.1	13.68	64.44	1480.


TEMPERATURE, C
0
4
8
12
16
0
300
600
900
1200
1500
PRESSURE, DB
REF. NO. 78 - 4 - 43
49-2.0 N 130-40.0 W
MO.-6 DAY-20 GMT-19.1
31
32
33
34
35
SALINITY, O/OO

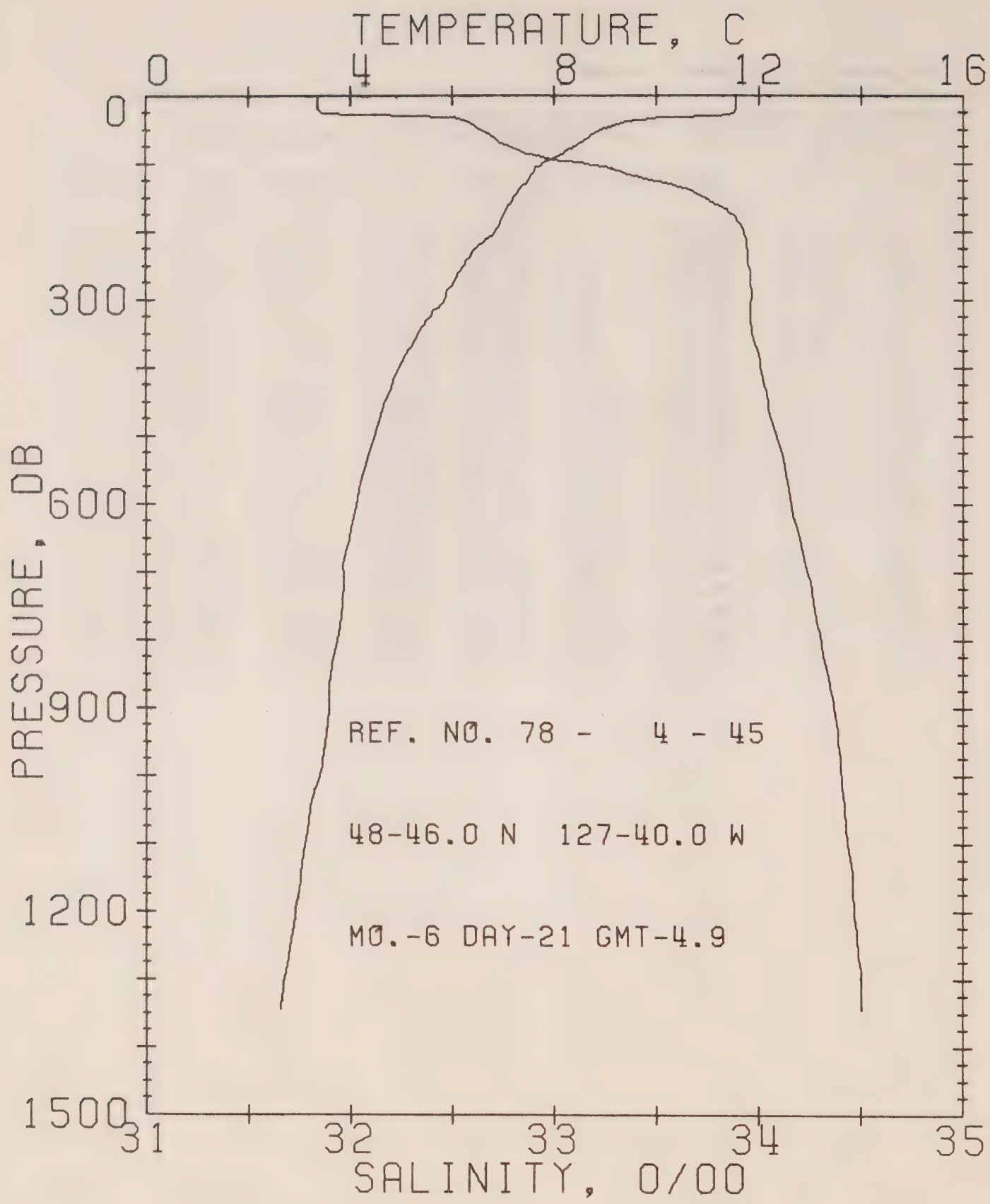
OFFSHORE OCEANOGRAPHY GROUP
REFERENCE NO. 78- 4- 43 DATE 20/ 6/78 STATION 6
POSITION 49- 2.0N, 130-40.0W GMT 19.1
RESULTS OF STP CAST 228 POINTS TAKEN FROM ANALOG TRACE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	DELTA D	POT. EN	SOUND
0	12.46	32.57	0	24.64	330.9	0.0	0.0	1496.
10	12.45	32.57	10	24.64	331.1	0.33	0.02	1496.
20	12.43	32.56	20	24.64	331.5	0.66	0.07	1496.
30	12.36	32.57	30	24.66	329.7	0.99	0.15	1496.
50	9.96	32.77	50	25.25	274.4	1.58	0.39	1488.
75	8.79	32.79	75	25.45	255.7	2.24	0.81	1484.
100	7.82	32.85	99	25.64	237.5	2.85	1.36	1481.
125	7.15	33.12	124	25.94	209.2	3.42	2.00	1479.
150	6.73	33.53	149	26.32	173.3	3.90	2.67	1478.
175	6.83	33.86	174	26.57	150.6	4.29	3.33	1480.
200	6.53	33.95	199	26.68	140.1	4.66	4.02	1479.
225	6.15	33.94	223	26.72	136.4	5.00	4.77	1478.
250	5.86	33.94	248	26.76	133.1	5.34	5.59	1477.
300	5.38	33.95	298	26.82	127.1	5.99	7.41	1476.
400	4.68	34.03	397	26.97	114.0	7.20	11.70	1475.
500	4.43	34.11	496	27.06	106.2	8.30	16.74	1476.
600	4.04	34.16	595	27.14	98.8	9.32	22.49	1476.
800	3.46	34.27	793	27.29	85.7	11.15	35.49	1477.
1000	3.23	34.41	991	27.42	74.5	12.74	50.02	1479.
1200	2.80	34.46	1188	27.50	67.3	14.15	65.85	1481.


TEMPERATURE, C
0
4
8
12
16
0
300
600
900
1200
1500
PRESSURE, DB
REF. NO. 78 - 4 - 44
48-51.0 N 128-40.0 W
MO.-6 DAY-21 GMT-1.4
31
32
33
34
35
SALINITY, O/OO

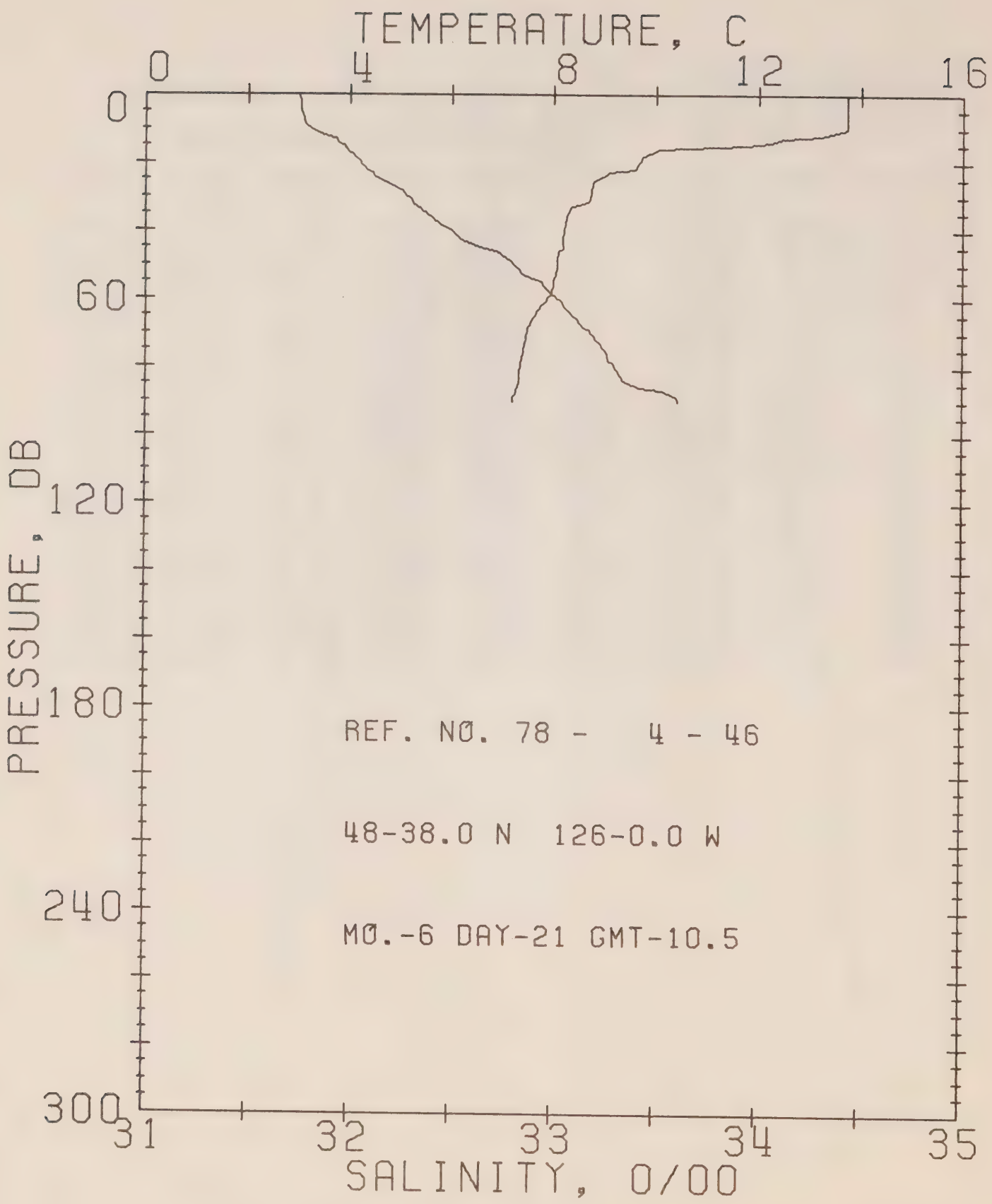
OFFSHORE OCEANOGRAPHY GROUP
REFERENCE NO. 78- 4- 44 DATE 21/ 6/78 STATION 5
POSITION 48-51.0N, 128-40.0W GMT 1.4
RESULTS OF STP CAST 184 POINTS TAKEN FROM ANALOG TRACE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	DELTA D	POT. EN	SOUND
0	12.19	32.40	0	24.56	338.6	0.0	0.0	1495.
10	12.20	32.40	10	24.56	339.2	0.34	0.02	1495.
20	12.20	32.40	20	24.56	339.4	0.68	0.07	1495.
30	11.59	32.47	30	24.73	323.7	1.01	0.15	1493.
50	8.72	32.64	50	25.34	265.4	1.57	0.38	1483.
75	8.26	32.89	75	25.60	240.6	2.21	0.79	1482.
100	7.82	33.25	99	25.95	208.1	2.77	1.28	1482.
125	7.91	33.64	124	26.25	180.5	3.25	1.84	1483.
150	7.73	33.81	149	26.40	166.0	3.68	2.44	1483.
175	7.42	33.91	174	26.53	154.5	4.08	3.10	1482.
200	7.10	33.96	199	26.61	147.0	4.46	3.82	1481.
225	6.87	33.97	223	26.65	143.4	4.82	4.60	1481.
250	6.68	33.98	248	26.68	140.5	5.18	5.46	1481.
300	6.27	33.99	298	26.74	135.1	5.87	7.39	1480.
400	5.52	34.03	397	26.87	124.0	7.17	12.02	1478.
500	4.69	34.04	496	26.98	114.2	8.37	17.52	1477.
600	4.22	34.12	595	27.09	104.3	9.47	23.68	1476.
800	3.77	34.29	793	27.27	88.1	11.38	37.30	1478.
1000	3.41	34.38	991	27.38	78.5	13.04	52.48	1480.
1200	2.96	34.46	1188	27.48	69.1	14.51	68.95	1481.


TEMPERATURE, C
0
4
8
12
16
0
300
600
900
1200
1500
PRESSURE, DB
REF. NØ. 78 - 4 - 45
48-46.0 N 127-40.0 W
MØ.-6 DAY-21 GMT-4.9
31
32
33
34
35
SALINITY, 0/00

OFFSHORE OCEANOGRAPHY GROUP
REFERENCE NO. 78- 4- 45 DATE 21/ 6/78 STATION 4
POSITION 48-46.0N, 127-40.0W GMT 4.9
RESULTS OF STP CAST 167 POINTS TAKEN FROM ANALOG TRACE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	DELTA D	POT. EN	SOUND
0	11.54	31.84	0	24.25	368.5	0.0	0.0	1492.
10	11.54	31.84	10	24.25	368.9	0.37	0.02	1492.
20	11.54	31.84	20	24.25	369.1	0.74	0.08	1492.
30	11.19	32.28	30	24.65	330.9	1.10	0.17	1492.
50	8.95	32.63	50	25.30	269.2	1.67	0.40	1484.
75	8.40	32.78	75	25.50	250.5	2.32	0.81	1483.
100	7.78	33.14	99	25.87	215.3	2.91	1.34	1481.
125	7.47	33.50	124	26.20	185.0	3.41	1.91	1481.
150	7.19	33.73	149	26.42	164.3	3.84	2.51	1481.
175	7.00	33.87	174	26.55	151.8	4.23	3.16	1480.
200	6.84	33.93	199	26.62	145.9	4.61	3.87	1480.
225	6.44	33.94	223	26.69	139.9	4.96	4.65	1479.
250	6.21	33.95	248	26.72	136.7	5.31	5.48	1479.
300	5.85	33.97	298	26.78	131.3	5.98	7.35	1478.
400	4.94	34.01	397	26.92	118.5	7.23	11.81	1476.
500	4.47	34.09	496	27.04	108.3	8.36	17.00	1476.
600	4.11	34.16	595	27.13	99.9	9.40	22.80	1476.
800	3.74	34.30	793	27.28	86.5	11.25	35.97	1478.
1000	3.38	34.41	991	27.40	76.4	12.87	50.77	1480.
1200	2.91	34.47	1188	27.49	67.8	14.30	66.83	1481.

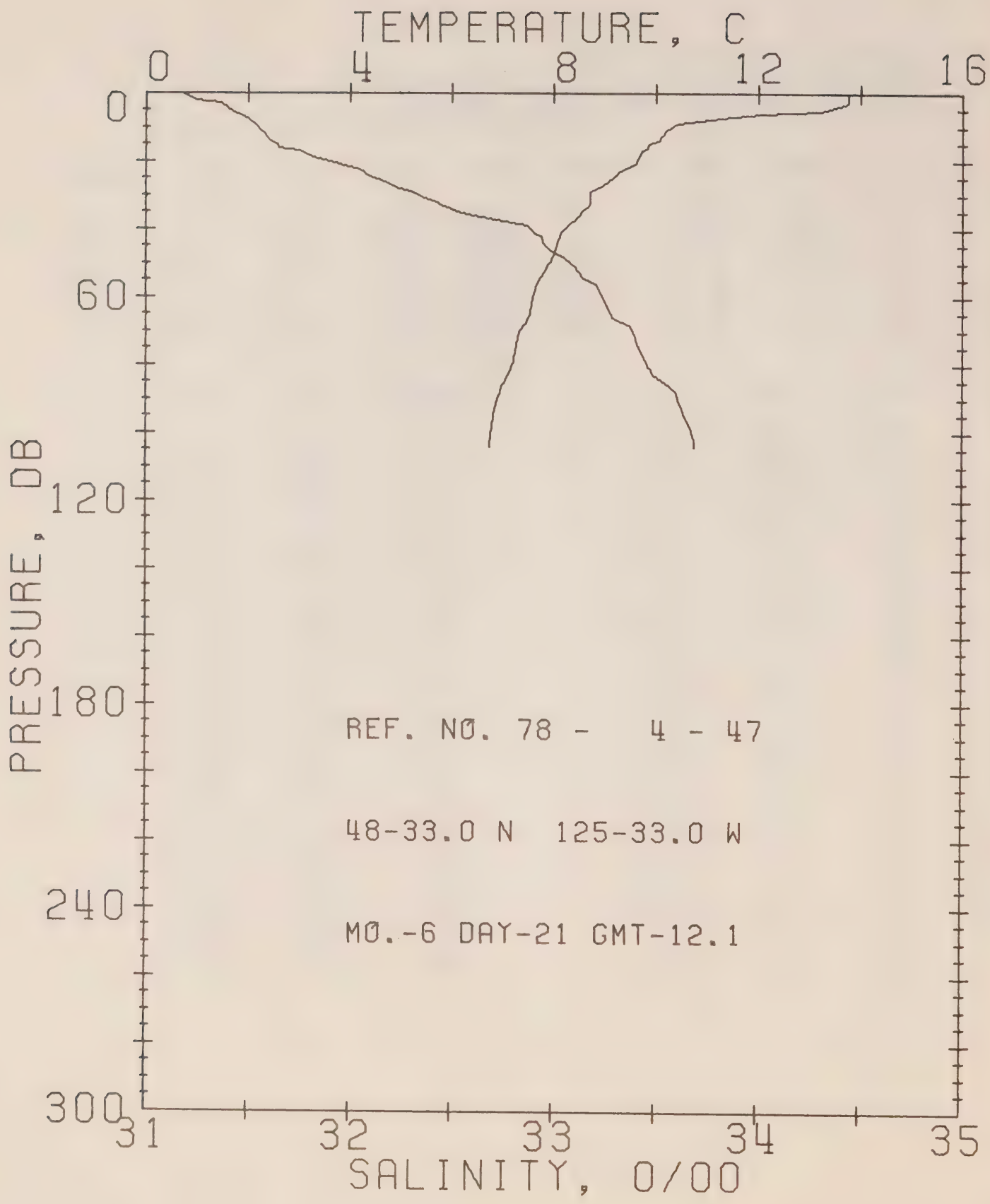

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16
0
60
120
180
240
300
PRESSURE, DB
REF. NØ. 78 - 4 - 46
48-38.0 N 126-0.0 W
MØ.-6 DAY-21 GMT-10.5
31
32
33
34
35
SALINITY, O/OO

OFFSHORE OCEANOGRAPHY GROUP
REFERENCE NO. 78- 4- 46 DATE 21/ 6/78 STATION 2
POSITION 48-38.0N, 126- 0.0W GMT 10.5
RESULTS OF STP CAST 49 POINTS TAKEN FROM ANALOG TRACE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	DELTA D	POT. EN	SOUND
0	13.73	31.75	0	23.76	415.0	0.0	0.0	1499.
10	13.72	31.81	10	23.81	410.8	0.41	0.02	1499.
20	9.68	32.05	20	24.73	323.1	0.77	0.08	1486.
30	8.73	32.28	30	25.06	292.0	1.08	0.15	1483.
50	8.07	32.80	50	25.57	243.9	1.62	0.37	1481.
75	7.42	33.25	75	26.01	202.2	2.17	0.72	1480.

DEPTH	TEMP	SAL
0.	13.73	31.75
3.	13.74	31.76
5.	13.73	31.76
6.	13.73	31.77
9.	13.73	31.78
10.	13.72	31.81
12.	13.22	31.87
13.	12.48	31.93
14.	12.25	31.94
15.	11.75	31.97
16.	10.07	31.98
18.	9.75	32.02
22.	9.61	32.08
23.	9.10	32.11
24.	8.99	32.12
25.	8.81	32.16
28.	8.76	32.25
29.	8.75	32.26
31.	8.71	32.30
32.	8.60	32.31
33.	8.38	32.33
36.	8.26	32.40
38.	8.24	32.44
40.	8.21	32.50
43.	8.19	32.55

DEPTH	TEMP	SAL
45.	8.18	32.66
46.	8.10	32.72
49.	8.08	32.79
51.	8.07	32.82
53.	8.04	32.85
55.	8.01	32.94
56.	8.00	32.95
58.	7.97	32.98
61.	7.83	33.04
62.	7.76	33.05
65.	7.64	33.10
68.	7.53	33.14
69.	7.50	33.17
72.	7.46	33.21
75.	7.42	33.25
78.	7.38	33.27
79.	7.37	33.29
83.	7.34	33.33
84.	7.33	33.34
86.	7.31	33.42
87.	7.29	33.53
88.	7.26	33.58
89.	7.21	33.60
90.	7.19	33.61


TEMPERATURE, C
0
4
8
12
16
0
60
120
180
240
300
PRESSURE, DB
REF. NØ. 78 - 4 - 47
48-33.0 N 125-33.0 W
MØ.-6 DAY-21 GMT-12.1
31
32
33
34
35
SALINITY, 0/00

OFFSHORE OCEANOGRAPHY GROUP
REFERENCE NO. 78- 4- 47 DATE 21/ 6/78 STATION 1
POSITION 48-33.0N, 125-33.0W GMT 12.1
RESULTS OF STP CAST 60 POINTS TAKEN FROM ANALOG TRACE

PRESS	TEMP	SAL	DEPTH	SIGMA T	SVA	DELTA D	POT. EN	SOUND
0	13.77	31.18	0	23.31	457.7	0.0	0.0	1499.
10	10.32	31.54	10	24.23	370.5	0.42	0.02	1487.
20	9.64	31.88	20	24.61	334.9	0.77	0.07	1485.
30	8.72	32.33	30	25.10	287.9	1.08	0.15	1483.
50	7.91	33.09	50	25.81	220.4	1.58	0.35	1481.
75	7.27	33.42	75	26.16	187.7	2.09	0.67	1479.
100	6.78	33.68	99	26.43	162.4	2.52	1.06	1478.

DEPTH	TEMP	SAL	DEPTH	TEMP	SAL
0.	13.77	31.18	46.	8.04	32.98
2.	13.77	31.24	47.	8.03	33.01
3.	13.76	31.37	48.	7.99	33.05
5.	13.23	31.42	50.	7.91	33.09
6.	12.04	31.45	51.	7.89	33.10
7.	11.53	31.48	53.	7.80	33.13
9.	10.43	31.53	54.	7.76	33.14
11.	10.22	31.56	56.	7.68	33.21
14.	10.05	31.61	59.	7.62	33.23
15.	9.88	31.64	62.	7.58	33.25
16.	9.85	31.65	65.	7.55	33.28
17.	9.74	31.75	66.	7.52	33.29
19.	9.69	31.82	68.	7.45	33.37
21.	9.60	31.95	70.	7.33	33.39
22.	9.42	32.03	72.	7.30	33.40
23.	9.30	32.06	74.	7.28	33.41
24.	9.22	32.08	78.	7.23	33.44
26.	9.07	32.17	79.	7.22	33.45
28.	8.86	32.24	83.	7.12	33.49
29.	8.72	32.30	85.	7.05	33.55
31.	8.73	32.37	86.	6.98	33.57
32.	8.73	32.43	88.	6.95	33.60
33.	8.71	32.44	90.	6.91	33.61
34.	8.60	32.50	93.	6.86	33.63
35.	8.57	32.53	95.	6.84	33.64
36.	8.50	32.61	98.	6.80	33.67
39.	8.29	32.87	101.	6.77	33.68
41.	8.17	32.90	102.	6.77	33.69
42.	8.13	32.94	103.	6.75	33.69
44.	8.08	32.95	104.	6.74	33.69

Surface Salinity and Temperature Observations

(P-78-4)

SURFACE SALINITY AND TEMPERATURE OBSERVATIONS
CRUISE REFERENCE NUMBER 78- 4

DATE/TIME				SALINITY	TEMP	LONGITUDE
YR	MO	DY	GMT	0/00	C	WEST
78	5	5	1828	30.799		123-30
78	5	5	2022	31.406		124- 0
78	5	5	2155	31.581		124-30
78	5	5	2312	31.324		125- 0
78	5	6	46	30.059		125-33
78	5	6	256	31.019		126- 0
78	5	6	500	31.823		126-40
78	5	6	830	31.727	10.6	127-40
78	5	6	1205	32.011	10.1	128-40
78	5	6	1526	32.492	10.2	129-40
78	5	6	1810	32.474	10.1	130-40
78	5	6	2115	32.518	9.4	131-40
78	5	7	10	32.461	9.2	132-40
78	5	7	330	32.515	9.1	133-40
78	5	7	610	32.523	8.6	134-40
78	5	7	930	32.551	8.3	135-40
78	5	7	1227	32.593	7.8	136-40
78	5	7	1610	32.573b	7.8	137-40
78	5	7	1907	32.731	8.1	138-40
78	5	7	2250	32.692b	7.9	139-40
78	5	8	200	32.820b	7.8	140-40
78	5	8	530	32.775b	6.8	141-40
78	5	8	950	32.756	6.7	142-40
78	5	8	1500	32.778	6.3	143-40
78	5	9	0	32.834		ON STATION
78	5	10	0	32.815		ON STATION
78	5	11	0	32.812		ON STATION
78	5	12	0	32.815		ON STATION
78	5	13	0	32.814		ON STATION
78	5	14	0	32.810		ON STATION
78	5	15	0	32.812		ON STATION
78	5	16	0	32.787		ON STATION
78	5	17	0	32.779		ON STATION
78	5	18	0	32.777		ON STATION
78	5	19	0	32.772		ON STATION
78	5	20	0	32.765		ON STATION
78	5	21	0	32.778		ON STATION
78	5	22	0	32.780		ON STATION
78	5	23	0	32.786		ON STATION
78	5	24	0	32.801		ON STATION
78	5	25	0	32.796		ON STATION
78	5	26	0	32.788		ON STATION
78	5	27	0	32.778		ON STATION
78	5	28	0	32.785		ON STATION

SURFACE SALINITY AND TEMPERATURE OBSERVATIONS
CRUISE REFERENCE NUMBER 78- 4

DATE/TIME				SALINITY	TEMP	LONGITUDE
YR	MO	DY	GMT	0/00	C	WEST
78	5	29	0	32.776		ON STATION
78	5	30	0	32.788		ON STATION
78	5	31	0	32.789		ON STATION
78	6	1	0	32.788		ON STATION
78	6	2	0	32.771		ON STATION
78	6	3	0	32.768		ON STATION
78	6	4	0	32.768		ON STATION
78	6	5	0	32.768		ON STATION
78	6	6	0	32.777		ON STATION
78	6	7	0	32.770		ON STATION
78	6	8	0	32.767		ON STATION
78	6	9	0	32.771		ON STATION
78	6	10	0	32.749		ON STATION
78	6	11	0	32.747		ON STATION
78	6	12	0	32.742		ON STATION
78	6	13	0	32.761		ON STATION
78	6	14	0	32.740		ON STATION
78	6	15	0	32.749		ON STATION
78	6	16	0	32.743		ON STATION
78	6	17	0	32.744		ON STATION
78	6	18	0	32.745		ON STATION
78	6	18	2230	32.711	8.9	143-40
78	6	19	312	32.710	9.4	142-40
78	6	19	800	32.766	9.3	141-40
78	6	19	1019	32.790	9.8	140-40
78	6	19	1343	32.696	9.9	139-40
78	6	19	1630	32.842	10.5	138-40
78	6	19	2015	32.553	10.5	137-40
78	6	19	2305	32.628	10.7	136-40
78	6	20	248	32.634	11.3	135-40
78	6	20	545	32.599	11.2	134-40
78	6	20	922	32.444	11.9	133-40
78	6	20	1225	32.535	12.1	132-40
78	6	20	1612	32.512	12.4	131-40
78	6	20	1905	32.446	12.5	130-40
78	6	20	2230	32.436	12.5	129-40
78	6	21	111	32.290	12.7	128-40
78	6	21	456	31.757	11.5	127-40
78	6	21	815	31.780		126-40
78	6	21	1025	31.643		126- 0
78	6	21	1205	31.081		125-33
78	6	21	1348	31.204		125- 0
78	6	21	1550	31.133		124-30
78	6	21	1730	31.517		124- 0

SURFACE SALINITY AND TEMPERATURE OBSERVATIONS
CRUISE REFERENCE NUMBER 78- 4

DATE/TIME				SALINITY	TEMP	LONGITUDE
YR	MO	DY	GMT	0/00	C	WEST
78	6	21	1905	30.905		123-30

b DENOTES SALINITY SAMPLE TAKEN FROM A BUCKET. ALL OTHER SAMPLES TAKEN FROM THE SEAWATER LOOP

LIST OF OMISSIONS FROM DATA

Hydrographic Data:

Consec. #	Depth (m)	T	S	O_2	Notes 1	2	3	Comments
14	4030		*			*		
17	567		*			*		
	1501		*			*		
25	3721		*				*	
30	498		*					no sample
34	1508		*		*			

Notes (MacNeill, 1977):

1. The data is suspect because of a reversal of gradient by >.01 ^{o}/oo (salinity) or >.08 ml/ℓ (oxygen).

2. The data is deleted beacuse of very irregular data values (usually a mistripping or leaking bottle if both oxygen and salinity are irregular).

3. The data is deleted because duplicate samples at a depth were not within .01 ^{o}/oo (salinity) or .08 ml/ℓ (oxygen).

STP Data:

Consecutive Number	Comments
20	omitted; wrong depth scale

25190